SCIENCE AND TECHNOLOGY

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Note to Students

Dear Students,

PT 365 document comprehensively covers the important current affairs of the last 1 year (365 days) in a consolidated manner to aid Prelims preparation.

In our endeavour to make this document more **effective** and **revision-friendly,** the following additions have been incorporated:

Summarised infographics: It includes aspects like

Key Application:
Applications of technologies such as **Gene Editing, Quantum Technology,** etc. are presented concisely.

Working of Technologies:
Complex processes like **CAR-T Therapy, Brain–Computer Interfaces** etc. are explained using simplified visual logic.

Concept Corner

- Key Concepts/Technologies have been covered holistically, followed by related developments.
- It will enhance the readability and comprehension of the subsequent articles.

Tables: Well-structured tables have been used to present key features and aspects of Space missions & satellites, Missiles, etc.

Quiz: QR-based Smart Quiz will test your knowledge and ensure a more engaging and effective learning process.

Remember, success is the result of small, consistent efforts repeated every day. Stay disciplined, revise regularly, and trust the process.

Best Wishes,
Team VisionIAS

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1. BIOTECHNOLOGY

1.1. GENE TECHNOLOGY

Genes and Related Concepts

- **Gene:** Section of a long molecule called **deoxyribonucleic acid (DNA).** And, are units of hereditary information.
  - **DNA** found in human cells along with **Ribonucleic acid (RNA).**
  - The Nobel laureate **James Watson** co-credited with the discovery of **DNA's double-helix structure** died recently.
- **Genome:** It is the entire set of DNA instructions found in a cell.
- **Chromosomes:** It is a thread-like structure made up of DNA.
- **Gamete:** It is the mature reproductive or **sex cell** that contains a haploid number of chromosomes (i.e., 50% of the genetic material or only one set of dissimilar chromosomes) and is capable of fusing with another haploid reproductive cell to form a diploid zygote.

Genome Sequencing

- Determines the exact order of base pairs in an individual's DNA strand.

Key Applications of Genome Sequencing

- **Predictive diagnostics** and **personalized healthcare** Enable treatments for genetic diseases
- **Paternity Testing** Confirms biological relationships
- **Agricultural** Identifying **traits for higher yield,** disease resistance, and climate resilience.

1.1.1. GENE EDITING

Why in the News?

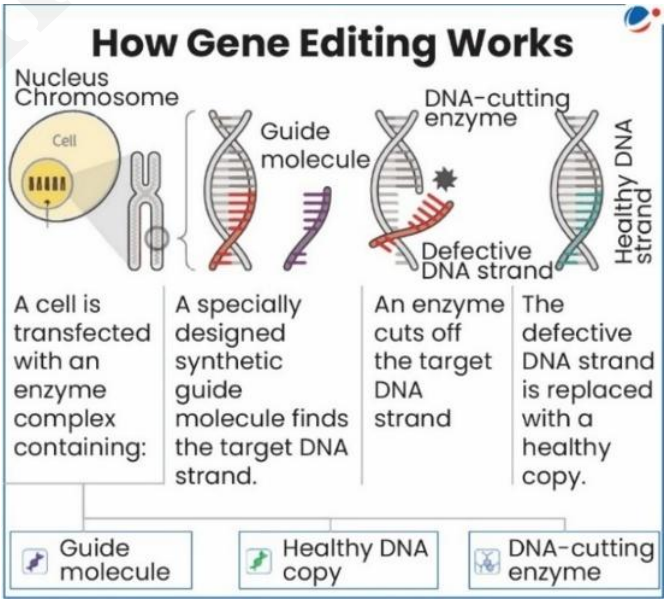
India's first gene-edited sheep has been produced by researchers from Kashmir University in collaboration with ICAR using **CRISPR-Cas9 technology.**

More on the News

- **Myostatin gene** in a lamb was edited, boosting muscle growth by **30%** (a trait found in some European breeds, such as the Texel, but absent in Indian breeds).
- **No foreign DNA** was added, making it **different from transgenic animals.**

About Gene Editing (or Genome Editing)

- A technology that can **change DNA sequences at one or more points** in the strand.



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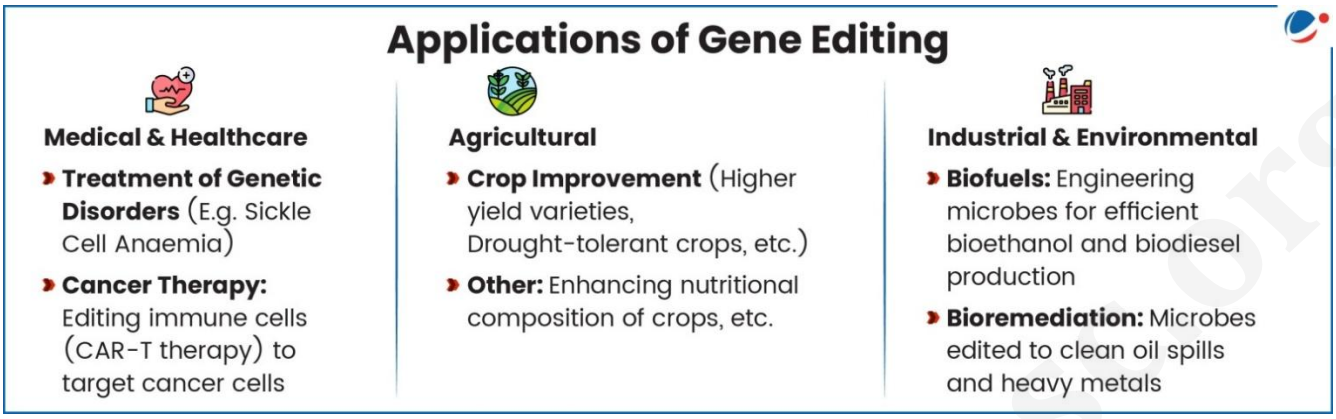
- It also involves **removing or changing** a **single base** or insert a new gene altogether.

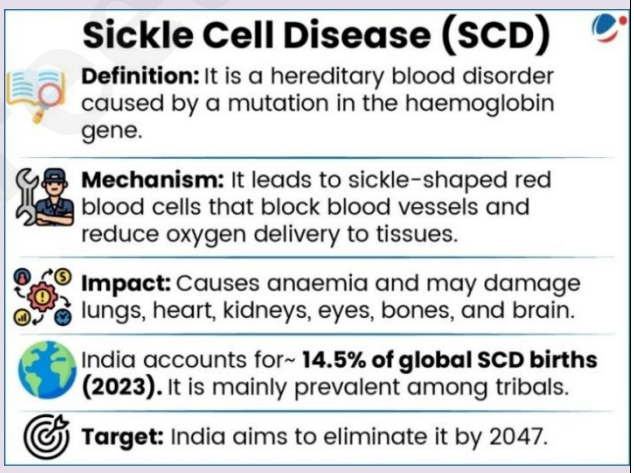
- **Types of Gene Editing**
  - **Somatic genome editing**: Alteration of cells **that do not contribute to gamete formation** and thus **cannot be passed on from the individual to offspring.**
  - **Germline genome editing:** Genetic modification of reproductive cells or embryos that creates changes which can potentially be passed down to future generations.
- **Techniques used:**
  - **ZFNs (Zinc Finger Nucleases):** Cuts DNA at precise locations
  - **TALENs (Transcription Activator-Like Effector Nucleases)**: Cuts DNA at precise locations
  - **CRISPR/Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)/Cas9):** Uses a small piece of RNA to guide the Cas9 "cutting" protein to the exact spot in the DNA.
  - **Homing Endonucleases (Meganucleases):** These are natural enzymes that can find and cut long sections of DNA.



Related News

BIRSA-101

- India launched its 1st indigenous CRISPR-based **gene editing therapy** called BIRSA-101 for **Sickle Cell Disease (SCD)**.
  - Also, a technology transfer agreement has been signed between **CSIR-IGIB** and **Serum Institute of India** which aims to enable scalable, affordable **enFnCas9 CRISPR**-based therapies for **SCD** and other genetic disorders.
- **About BIRSA-101**
  - It has been developed by **CSIR–Institute of Genomics & Integrative Biology (IGIB).**
  - **It has been called BIRSA-101 as it has been** dedicated to **Bhagwan Birsa Munda** on his 150th birth anniversary.



GlowCas9

- Scientists from **Kolkata-based Bose Institute**, an autonomous institute under Dept. of Science and Technology (DST), have developed **GlowCas9**.
- It is a CRISPR protein that lights up while performing gene editing.
- It emits light because it is fused with **nano-luciferase fragments from deep-sea shrimp,** which reassemble and emit light when the Cas9 protein folds correctly.

Epigenome Editing

- It regulates gene expression by modifying the **epigenome** without changing the DNA sequence.

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- **Epigenome** consists of chemical compounds that modify, or mark, that regulate gene expression
- Unlike traditional gene editing methods that involve cutting DNA, epigenome editing allows for precise control over gene expression (with reversible changes), making it a safer alternative.

1.1.2. GM CROPS

Why in the News?

NITI Aayog Member called for adopting GM Crops for Self-Sufficiency in Edible Oils.

About GM Crops

- GM Crops are the **Genetically Modified Organisms (GMOs),** i.e. their **genetic material (DNA) has been altered artificially** for desirable features like robustness, pest resistance among other.
  - **Transgenic**s are a subset of GMO where **one or more DNA sequences from another species** have been introduced artificially. E.g., **Bt. Cotton-** contains a gene from a bacterium.

Adoption Status in India

- **Bt cotton** is the only GM crop approved for cultivation.
- **Bt-Brinjal:** Bt-brinjal was cleared by GEAC for commercial cultivation, but it was put on a **moratorium.**
- The **Centre conditionally approved** herbicide-tolerant **GM mustard (DMH-11)** for release into the environment.
  - However, this approval is currently **under review by the Supreme Court**.

Regulatory Framework of GM Crops in India

- **Food Safety and Standards Act, 2006:** Prohibits import, manufacture, use, or sale of GM food without FSSAI's approval.
- **Review Committee on Genetic Manipulation (RCGM):** Under the **Department of Biotechnology (DBT)**, this committee monitors various aspects of R & D projects involving GM organisms.
- **State Biotechnology Coordination Committee (SBCC):** Reviews the safety and control measures in various institutions handling Genetically Modified Organisms (GMOs).
- **District Level Committee (DLC):** Inspects, investigates, and reports to the SBCC or the **GEAC** about compliance.

Site Directed Nuclease (SDN)

- **SDN-1:** A site-directed mutagenesis **without using a DNA** sequence template.
- **SDN-2:** A site-directed mutagenesis **using a DNA sequenc**e template.
- **SDN-3:** A site-directed **insertion of gene/large DNA sequence** using a DNA sequence template.

Note: Genome editing of **Site Directed Nuclease 1 (SDN1)** and **SDN 2 types** of **genes** has been approved under **India's biosafety regulations** for general crops.

Genetic Engineering Appraisal Committee (GEAC)

Genesis: Constituted as a Statutory committee under the **"Rules for Manufacture, Use, Import, Export and the Storage of Hazardous Micro-organisations, Genetically Engineered Organisms or Cells, 1989 ".**

- The rules are framed under the **Environment (Protection) Act, 1986.**

Ministry: Ministry of Environment, Forest and Climate Change (MoEF&CC)

Responsibilities:

- **Appraisal of proposals relating** to the release of Genetically engineered (GE) organisms and products.
- **Appraisal of activities involving** large-scale use of hazardous microorganisms and recombinants in research and industrial production.

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Related News

Genome-Edited Rice

- **Indian Council of Agricultural Research (ICAR)** has developed **India's first genome-edited** (GE) **rice varieties** named as **DRR Rice 100 (Kamla)** and **Pusa DST Rice.**
  - Also, it became first country in the world to develop GE rice varieties.
  - These new varieties were developed using **Genome editing technology** based on **CRISPR-Cas**.
- **About Genome-edited Rice Varieties**
  - **DRR Dhan 100 Kamala: Developed by** ICAR–IIRR (Indian Institute of Rice Research), Hyderabad.
    - It is improvement of **'Samba Mahsuri' by** targeting the **CKX2 (Cytokinin Oxidase 2) gene.**
    - A **cytokinin** is a plant hormone that influences growth and the **stimulation of cell division**.
  - **Pusa DST Rice 1: Developed by** ICAR-Indian Agricultural Research Institute (IARI), New Delhi.
    - This variety is an **improved version** of the fine-grain rice **MTU1010 (**Cottondora Sannalu).

Note: These two new varieties contain no foreign DNA, and therefore are not considered GM Crops.

1.1.3. GENOME INDIA PROJECT

Why in the News?

Preliminary findings of the GenomeIndia Project published in the Journal Nature Genetics.

About GenomeIndia Project

- **Genesis**: **Initiated** by Department of Biotechnology (DBT) with **collaborations of 20 institutions** to map **India's genetic diversity.**
- **Objective:** Build a **comprehensive catalogue of genetic variations** that reflect unique diversity of Indian population.
- **Data Storage:** Indian Biological Data Centre (IBDC) at Faridabad (Haryana).
  - **IBDC** is India's **first national life science data repository**, supported by DBT.

Other Key Initiatives for Genome Sequencing

- **IndiGen program:** Initiated by the Council of Scientific and Industrial Research (CSIR).
- **'One Day One Genome' Initiative:** Initiated by DBT.
- **Human Genome Project (HGP):** An international collaboration that aimed to map and sequences the entire human genome.
- **100,000 Genomes Project**: England's very first initiative sequencing 100,000 genomes.
- **International HapMap Project:** Analyzing over a million variants in African, Asian, and European ancestry groups.

1.1.4. RELATED NEWS/DEVELOPMENTS

1.1.4.1. GENE-DRIVE TECHNOLOGY (GDT)

Gene Drive Technology (GDT) can stop insects from spreading vector borne diseases (mosquitoes) and pests that attack plants.

About GDT

- A type of genetic engineering technique that modifies genes to alter **Mendelian inheritance** (Normal).
  - **Mendelian inheritance refers** to certain patterns of how traits are passed from parents to offspring.
- Increases the likelihood that a particular suite of genes will be passed onto the next generation.

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- **Key Components**: Gene, Cas9 enzyme and CRISPR

1.1.4.2. ORGAN-ON-CHIP (OOC) TECHNOLOGY

Organ-on-a-chip (OoC) can transform drug development.

About Organ-on-a-chip (OoC)

- Refers to micro-scale system used for mimicking the **human body environment**.
  - It is one of the **human-relevant 3D** culture models, also known as 'New Approach Methods' (NAMs).
  - **3D culture** system allows researchers to recreate human organs and diseases in one dish.
- **Mechanism**: Cells are placed on a chip and allowed to grow into 3D structures with the help of a polymer that resembles real tissue in the human body.
- **Benefit**: Provides a human-relevant, ethical, and cost-effective platform for accurate drug testing, disease modeling, and personalized medicine.

1.1.4.3. RNA SILENCING

The Antiviral agent developed by Germany based researchers **using RNA silencing** provides protection against **cucumber mosaic virus (CMV),** responsible for **25-30% yield losses** in banana plantations.

- Techniques used by researchers to strengthen plant immunity against CMV include **Host-Induced Gene Silencing (HIGS)** and **Spray-Induced Gene Silencing (SIGS)**.

What is RNA Silencing?

- RNA silencing is a gene regulation mechanism that reduces gene expression by either suppressing transcription (**transcriptional gene silencing** [TGS]) or degrading specific RNA after transcription (posttranscriptional gene silencing [PTGS]/RNA interference [RNAi]).
  - It can **turn down or completely shut off** the activity of specific genes.
- RNA silencing **involves small RNA molecules (like siRNA or miRNA)** that can bind to messenger RNA (mRNA).
  - When these small RNAs bind to mRNA, they either:
    - **Destroy the mRNA** (so the protein can't be made)
    - **Block the mRNA f**rom being read by the cell's protein-making machinery

microRNA (miRNA)

- A small non-coding RNA that helps cells regulates gene expression.
  - It controls gene expression by binding with mRNA and preventing them from being translated into proteins or by degrading or destroying mRNA altogether.
- Proteins in the nucleus regulate **RNA transcription** and splicing while **microRNAs** control the **translation** and **degradation** of mRNA in the cytoplasm.
  - **Transcription** copies a gene's DNA sequence into mRNA, and **translation** decodes that mRNA into a specific protein.

1.1.4.4. PANGENOME

Chinese Scientists created first Pangenome of Asian rice with the help of '**PacBio high-fidelity' (HiFi) sequencing technology.**

- **'high-fidelity' (HiFi) Sequencing Technology** is a **single-molecule, real-time sequencing technology (SMRT)** that provides incredible single-molecule read accuracy across long reads.
- It is a kind of **Long-read sequencing method** of **genome sequencing.**

What is a Pangenome?

- Collection of **genome sequences** from many individuals of the **same species**.
- **Key Applications:**
  - **Agriculture**: Helps in introducing new traits for disease-tolerance as well as resilience in crops against climate shocks.

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- **Precision Medicine**: In humans, helps in identifying **population-specific genetic markers** for diseases. E.g. Human Pangenome Project.

1.1.4.5. SHUKR GENE

Researchers from **CSIR- Centre for Cellular and Molecular Biology (CCMB), Hyderabad,** shed light on the molecular innovations in flowering plants that help explain **abominable mystery** through newfound gene, called **SHUKR (or sperm).**

About SHUKR Gene

- Controls a group of genes called **F-box,** which help **manage proteins** involved in **developing healthy pollen.**
- SHUKR and its F-box genes **evolve fast,** explaining Darwin's "**abominable mystery**" or the sudden **rise** and **success of flowering plants** in evolutionary history.

1.1.4.6. DNA PROFILING

DNA Identification/profiling used to identify suspects or victims at Red fort blast site.

About DNA Profiling (also called DNA fingerprinting)

- A technique used to identify individuals by analyzing unique patterns in their DNA.
  - Based upon the **variability between individuals of several noncoding regions of DNA**, called **VNTRs (Variable Number of Tandem Repeats)**.
- **Key Methods**
  - **Short Tandem Repeat (STR):** Examines short repeating DNA sequences in the nucleus.
  - **Mitochondrial DNA (mtDNA)**: Used if nuclear DNA is degraded.
  - **Y chromosome**: Focuses on STRs on the Y chromosome, inherited father to son. Identifies male victims by matching paternal male relatives.
  - **Single Nucleotide Polymorphisms (SNPs)**: SNPs are single-base differences unique to individuals, matched with personal items like toothbrushes.

1.1.4.7. JUMPING GENES

A new study reveals that **LINE-1**, a **jumping gene,** binds to **cellular DNA during brief periods** of cell division.

- Also, recently, ICAR patented **Transposon-associated proteins (TnpB)** based-Genome Editing technology.

About Jumping Gene (Transposable Elements)

- These are **DNA sequences** that **move from one location to another on the genome** thus **affecting the expression of genes**.
  - They can do so either by **physically cutting and pasting themselves or by copying themselves to new locations.**
  - In the process, they may cause **mutations and increase (or decrease) the amount of DNA** in the cell genome.
- In human beings, more than **50% of the genome** is composed of **transposable elements**.

1.2. CHIMERIC ANTIGEN RECEPTOR T-CELL (CAR-T) THERAPY

Why in the News?

NexCAR19, India's first indigenous CAR T-cell therapy, has been unveiled by the Prime Minister.

More on the News

- **NexCAR19 therapy** has been developed for **B-cell blood cancers** by ImmunoACT (a company incubated under IIT Bombay, and Tata Memorial Hospital), supported by DBT and Biotechnology Industry Research Assistance Council (BIRAC).

www.freeupsc.org

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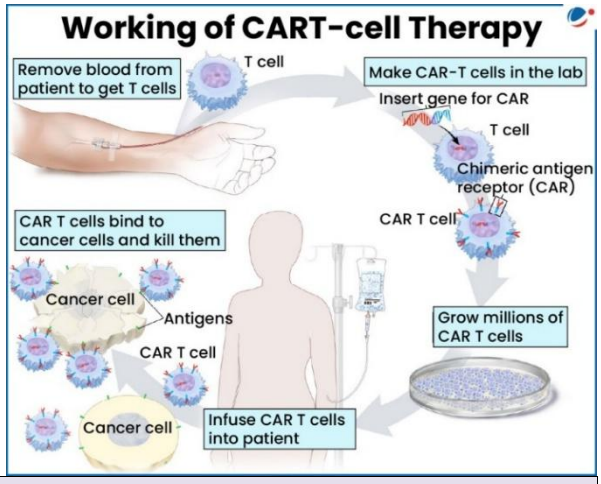
- Earlier, Central Drugs Standard Control Organisation (CDSCO) has approved **Qartemi**, a CAR T-cell therapy for treating blood cancer.

What is Chimeric Antigen Receptor T-cell (CAR-T) Therapy?

- In it, patient's **T cells** are collected from the blood and genetically modified in a laboratory.
- A special receptor called **CAR (Chimeric Antigen Receptor)** is added to these T cells, enabling them to recognize and attack cancer cells more effectively.
- It is considered as a "**living drug**".



Advantages of CAR-T therapy	Challenges
• **Long Term Remission:** CAR-T therapy can keep cancer at bay for long periods, reducing treatment cycles. • **Personalized Treatment:** CAR-T uses a patient's own modified T-cells. • **Short treatment Duration:** Entire process takes approximately 45 days.	• **Cytokine Release Syndrome: It** is a systemic inflammatory response caused by cytokines released from infused CAR T cells, which can lead to organ dysfunction. • **Antigen Escape:** Tumors develop resistance by losing antigen targeted by CAR-T cells. • **Other:** Neurotoxicity, etc.

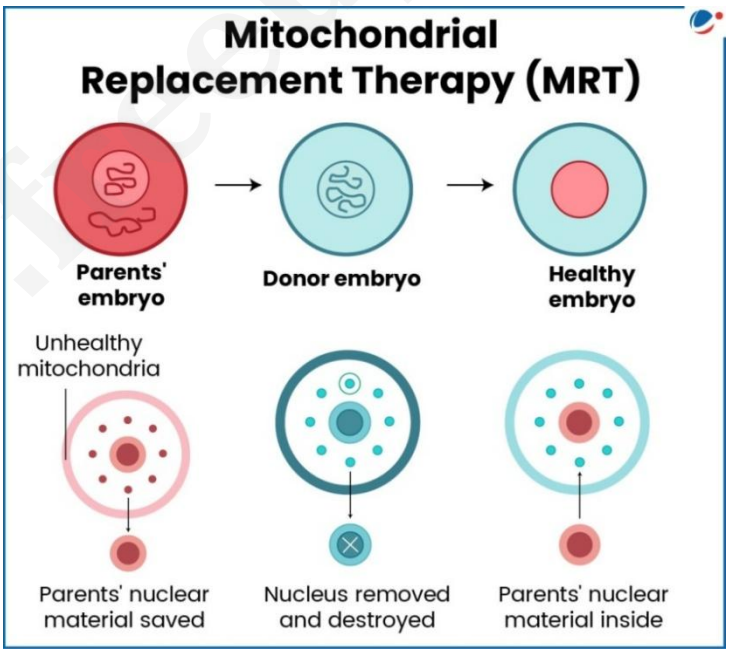
1.3. MITOCHONDRIAL REPLACEMENT THERAPY (MRT)

Why in the News?

A clinical trial in United Kingdom successfully protected eight babies, at high risk of inheriting '**mitochondrial diseases'** from their moms, through **mitochondrial donation or Mitochondrial Replacement Therapy (MRT)**.

What is Mitochondrial Disease?

- **Mitochondria:** They are **tiny "power plants" inside almost every cell in our body.** They generate more than 90% of the energy in cells.
- **Mitochondrial DNA:** Mitochondria have their own DNA, distinct from nuclear DNA. Affects energy production but not physical characteristics.
- **Mitochondrial Disease:** When the mitochondria **are not working properly**, cells don't have **enough energy** and they **begin to die.** When **too many cells die**, **whole organ systems can fail**, which **can be life-threatening.**
    - Mitochondrial diseases are **exclusively inherited from the child's mother.**



About Mitochondrial Replacement Therapy (MRT)

- A new form of reproductive **in vitro fertilization (IVF)** which works on the principle of replacing a women's abnormal mitochondrial DNA (mt-DNA) with the donor's healthy one.

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- **In MRT an embryo contains:**
  - **Nuclear DNA** from **a man** and **a woman** (the prospective mother)
  - **Mitochondria in an egg** donated by another woman (the mitochondrial donor).
- Since, the child born will **have three distinct genetic materials**, it is called a **Three-Parent Baby.**
- **Techniques:** MRT include different techniques like **Maternal Spindles Transfer (ST)** and **Pronuclear Transfer (PNT).**
  - PNT is done after fertilization whereas MST is done before fertilization.

1.4. STEM CELLS

Why in the News?

Recently, a study has found that **stem cells extracted from adipose tissue (body fat)** can aid in the healing of **osteoporosis-related fractures in humans**.

More on the News

- **Osteoporosis** is a disease which makes bones weak and fragile.

About Stem Cells

- **Meaning:** They are **unspecialized cells** that can **self-renew indefinitely** and can also **differentiate into more mature cells** with **specialized functions.**
  - In humans, they have been identified in **inner cell mass of the early embryo**; in some tissues of **foetus, umbilical cord, placenta**; and in **several adult organs.**
- **Key Types: Pluripotent" stem cells** (embryonic stem cells and induced pluripotent stem cells) and **Nonembryonic/Somatic/Adult stem cells.**
  - **Pluripotent stem cells**: Ability to differentiate into all cells of the adult body.
    - **Embryonic Stem Cells (ESCs):** Found in the embryo (3-5 days post fertilization and prior to implantation) containing an inner cell mass capable of generating to all the specialized tissues of human body.
    - **Induced Pluripotent Stem Cells (iPSCs):** Created through the introduction of embryonic genes into a **somatic cell** (For E.g. Skin Cell) causing it to revert back to a "stem cell like" state.
  - **Adult Stem Cells (ASCs): Undifferentiated** cells found in tissue or organ and can differentiate to **yield the specialized cell types of that tissue or organ**.
    - Key Types Include: Neural Stem Cells; Skin Stem Cells, etc.

Related News

Animal Stem Cell Biobank

- India's **first state-of-the-art animal stem cell biobank and laboratory** inaugurated at **National Institute of Animal Biotechnology (NIAB),** Hyderabad.
- **About Animal Stem Cell Biobank**
  - **Key Features:** Stem cell culture unit, 3D bioprinter, bacterial culture lab, cryostorage, etc.
  - **Significance:** Focus on **regenerative medicine and cellular therapies for livestock;** advance research in **disease modelling, tissue engineering, etc.**
  - **Supported by: National Biopharma Mission (NBM)** of Department of Biotechnology – BIRAC.
    - NBM is an **industry-Academia Collaborative Mission** for accelerating biopharmaceutical development.

1.5. PHENOME INDIA NATIONAL BIOBANK

Why in the News?

National Biobank inaugurated at the CSIR-Institute of Genomics and Integrative Biology (IGIB).

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About National Biobank

- **Launched under** Phenome India Project.
  - **It is based** on the **UK Biobank model,** but customized for Indian diversity.
- **Purpose:** It will aid in early diagnosis, improve therapeutic targeting, and bolster the fight against complex diseases such as diabetes, cancer, and rare genetic disorders.
  - It will **generate high-resolution data** that can **power AI-driven diagnostics** and **gene-guided therapies**.
- **Coverage:** It will collect comprehensive genomic, lifestyle, and clinical data from **10,000 individuals**.

About Phenome India Project

- Officially called as **Phenome India-CSIR Health Cohort Knowledgebase (PI-Check).**
- **Launched by:** Council of Scientific and Industrial Research (CSIR)**.**
- **Objective:** It is designed to be a long-term, data-rich study tracking the health trajectories of individuals over several years.

What is Phenome?

- **Phenome** is the entire set of **phenotypes** in a cell, tissue, organ, organism or species.
- **Phenotype** refers to the **observable physical characteristics** of an **organism**.
  - These include the organism's **appearance, development, and behavior.**
  - An organism's **phenotype** is determined by its **genotype** as well as by env**ironmental influences** upon these genes.

1.6. OTHER IMPORTANT NEWS/DEVELOPMENTS

1.6.1. BIOCHEMICAL MARKERS

Indian researchers have identified **biochemical markers in the blood** that could help **detect kidney complications in diabetic patients**.

About Biochemical Markers

- **Meaning:** They are **small molecules (**like sugars, amino acids, lipids) **produced during metabolic processes** in the body and are used by doctors **for ascertaining disease risks**.
  - **For e.g.,** cholesterol tests are used to assess heart disease risk.
- **Components for identifying kidney complication**: arabitol, myo-inositol, ribothymidine, etc.

1.6.2. NATIONAL BIOFOUNDRY NETWORK

India's first **National Biofoundry Network** was launched in **August 2025,** which also marked the first anniversary of India's **BioE3 Policy.**

- **Biofoundry** is an automated facility that rapidly designs, builds, and optimizes engineered organisms by integrating DNA synthesis, gene editing, and high-throughput biomanufacturing workflows.

About National Biofoundry Network

- **Objectives:** Aid in the scale-up of proof-of-concept projects into viable technologies.
- **Component** of BioE3 Policy, categorized as **Bio enablers**.
- **Functions:** Scaling up research activities

About BioE3 Policy

- **BioE3 (Biotechnology for Economy, Environment and Employment) Policy** is India's first policy in Biotechnology.
- Launched by the **DBT,** under Ministry of Science & Technology.
- Aims to **revolutionize biomanufacturing** which includes sectors like **precision biotherapeutics, carbon capture and utilisation, functional foods and smart proteins,** etc.

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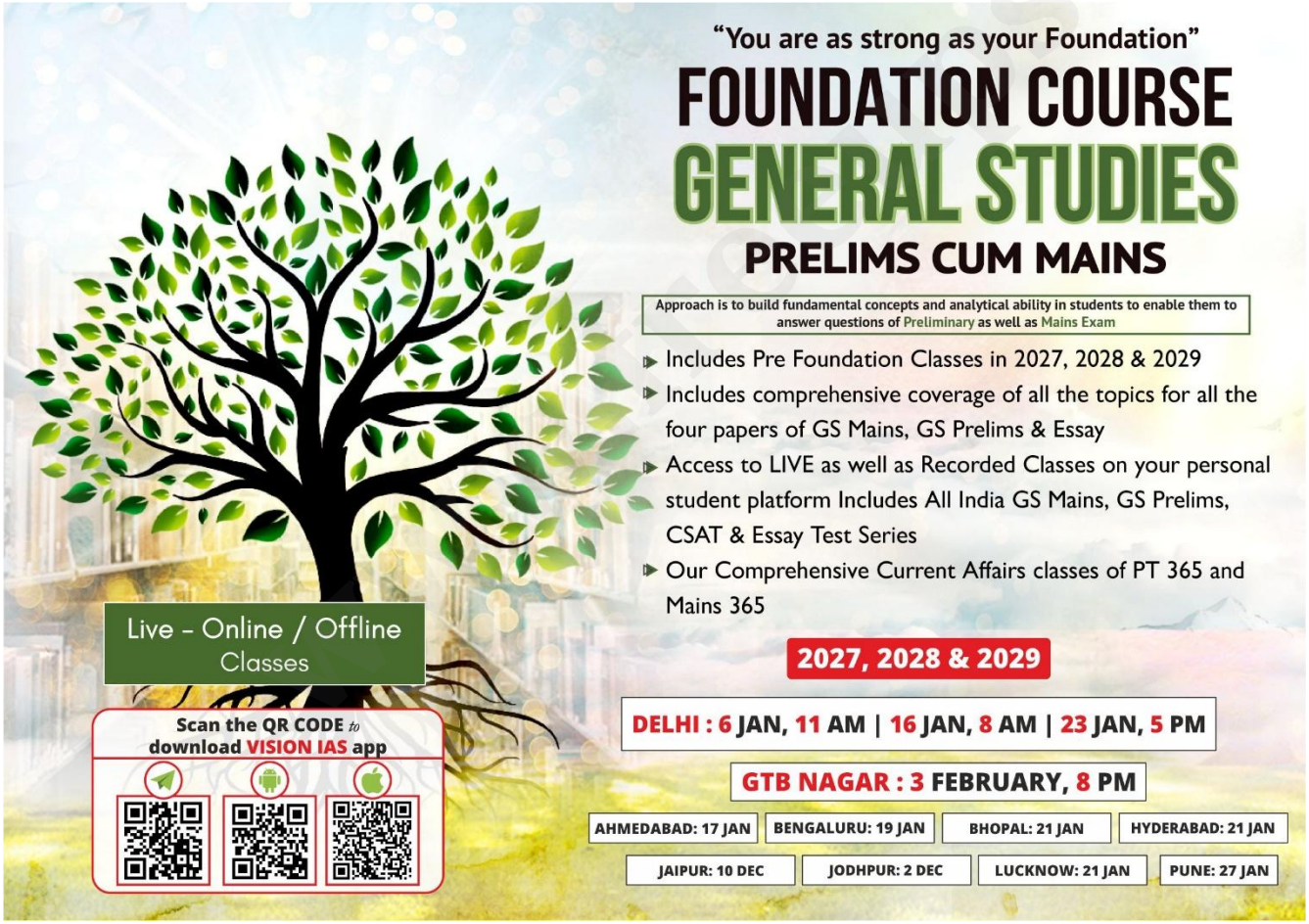
1.6.3. DIVERSE EPIGENETIC EPIDEMIOLOGY PARTNERSHIP (DEEP) PROJECT

CSIR-Centre for Cellular and Molecular Biology (CCMB) is collaborating with research groups across the world on the Diverse Epigenetic Epidemiology Partnership (DEEP) project.

- **Epigenetics** is the study of how your behaviours and environment can cause changes that affect the way your genes work.
    - Unlike **genetic changes**, epigenetic changes are reversible and do not changes the DNA sequence, but they can change how body reads a DNA sequence.

About DEEP Project

- A five-year project led by researchers at the University of Bristol, London and the CSIR CCMB in India.
- **Objective**: Improve global health by exploring the effects of genomic and environmental diversity on disease risk across the global population.



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2. IT & COMPUTER

2.1. ARTIFICIAL INTELLIGENCE

Artificial Intelligence & Related Concepts

NCEPT Corner

AI

- It is a technology that enables computers and machines to simulate human learning, comprehension, problem solving, decision-making.

Stages of AI

Artificial Narrow Intelligence (ANI)

- **Stage One:** Machines imitate human behaviour, specializing in **one area** to solve a problem.

Artificial General Intelligence (AGI)

- **Stage Two:** Machines can continuously learn and are **as smart as humans.**

Artificial Super Intelligence (ASI)

- **Stage Three:** It is superintelligent by being self-aware and intelligent enough to **surpass the cognitive abilities of humans.**

Machine Learning (ML)

- Enables AI to imitate the way that humans learn, gradually improving its accuracy.
  - **Supervised learning:** It uses labeled datasets to train algorithms to predict outcomes and recognize patterns.
  - **Unsupervised learning:** It uses algorithms to analyze and cluster unlabeled data sets.

Natural language processing (NLP)

- Machine learning technology that enables computers to interpret and comprehend human language.

Neural Networks

- Computational models that are influenced by the human brain's neural structure.

Deep learning

- It is a type of machine learning that uses artificial neural networks to learn from data, similar to the way we learn.

Large Language Models (LLMs)

- An AI system that can understand and generate text, built on a neural network known as the **transformer architecture.**
  - **Multimodal LLM:** These are LLM trained on large datasets including both text and non-textual data (image, audio, video, etc.)

Generative Pre-trained Transformer (GPT)

- refers to a family of LLM that can understand and generate text in natural language.
  - **Generative:** A technology capable of producing content, such as text and imagery.
  - **Pre-trained:** Pre-trained models are saved networks that have already been taught, using a large data set, to resolve a problem or accomplish a specific task.
  - **Transformer:** A deep learning architecture that transforms an input into another type of output.

Agentic AI

- AI systems that can autonomously make decisions, take actions and adapt to changing environments. E.g., India's first agentic **AI Kruti.**

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2.1.1. BHARAT GEN

Why in the News?

Ministry of Science & Technology launched 'Bharat Gen' at the BharatGen Summit.

About Bharat Gen

- **India's first-of-its-kind,** indigenously developed AI-based **Multimodal LLM** for Indian languages.
- **Public-Private Partnership Initiative**
  - **Launched** as a **non-profit company** with funding from the Department of Science and Technology.
- **Developed** under the **National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS)**
- Being implemented through **Technology Innovation Hubs (TIH) Foundation** for IoT (Internet of Things) and IoE (Internet of Everything) at **IIT Bombay.**
- **4 primary goals:**
  - **Creation of Bharat-centric foundational LLM models:** Focus on Indian languages, culture and tradition
    - It will cover all **22 scheduled Indian languages**.
  - **Bharat Data Sagar:** To centralise high-quality Bharatiya data necessary for model building.
  - **Startup Ecosystem and Innovation:** Empowering entrepreneurs with tools, mentorship, and collaboration to create innovative AI applications for India.
  - **Skilling and Capacity Building:** Strengthen India's AI talent pool

Other initiatives taken to promote AI Ecosystem in India

- **IndiaAI Mission (2024):** implemented by **'IndiaAI' Independent Business Division (IBD) under Digital India Corporation (DIC)** under **the ministry of Ministry of Electronics and Information Technology.**
  - It is based on 7 **pillars.**
- **India AI Governance Guidelines:** Unveiled by the Union Ministry of Electronics and Information Technology (MeitY) under the **IndiaAI Mission**.
- **National AI Portal (INDIAai):** Joint venture by MeitY, National e-Governance Division (NeGD) and NASSCOM.
- **AI Research Analytics and Knowledge Dissemination Platform (AIRAWAT):** For providing a common compute platform for AI research and knowledge assimilation.
- **Global Partnership on Artificial Intelligence (GPAI):** To guide the responsible development and use of AI.
  - **India** is a **founding member**.
- **Other**: National Strategy for AI (NSAI), National AI Skilling Program, YuvaAI initiative for Skilling and Capacity Building, **Srijan** (GenAI Centre of Excellence), etc.

Initiatives taken at Global Level

- **Europe's AI Act, 2024:** Europe's first major regulation on AI.
- **Bletchley Declaration, 2023**: Signed by 28 countries and EU, it establishes a shared understanding of the opportunities and risks posed by frontier AI.
- **Other:** G7 pact on AI (2023) etc.

2.1.2. DEEPFAKES

Why in the News?

Recently, the US enacted **Take It Down Act** to tackle harmful deepfakes online.

What are Deepfakes?

- **About:** Deepfake is a **video, photo**, or **audio recording** that seems real but has been **manipulated with AI** blurring the line between **reality** and **manipulation**.
- **Technology:** Deep learning techniques

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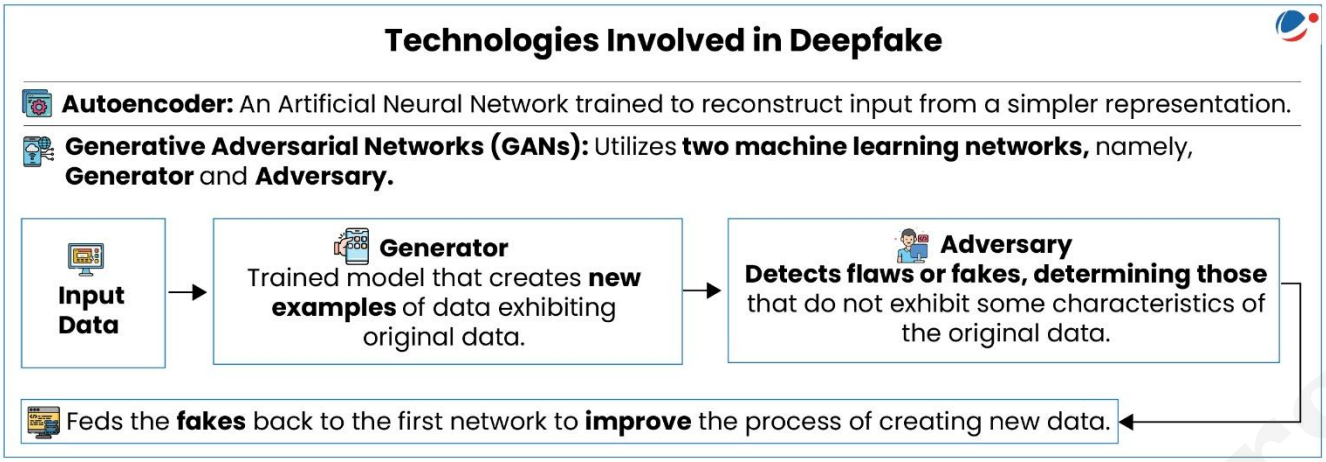
- It involves **replacing faces, manipulating facial expressions,** and **synthesising speech**.

- **Potential Applications:**
  - **Entertainment** (creative effect in movies).
  - **E-commerce** (creating customers likenesses for virtual trial of clothes).
  - **Communication** (Speech synthesis for speaking in another language), etc.



- **Regulation in India:**
  - India lacks specific laws for deepfakes and AI-related crimes.
  - **DPDP Act, 2023:** Penalises creation/use of deepfakes involving personal data without consent.
  - **Meity** proposed amendments to **Information Technology (Intermediary Guidelines and Digital Media Ethics Code) Rules, 2021 (IT Rules 2021)** to check misuse of Synthetically Generated Information (SGI), including Deepfakes.
    - It provides that Platforms enabling SGI creation must ensure labelling or permanent metadata/ identifier.

2.1.3. OTHER AI RELATED DEVELOPMENTS

Biomolecular Emulator (BioEmu)	• A new **deep learning system**, BioEmu-1, has been developed by **Microsoft** in collaboration with other researchers. • Predicts the full range of shapes a **protein naturally explores** under biological conditions.
AlphaGenome	• Launched by **Google DeepMind** to predict how individual mutations in human DNA affect their functions and impact our health. ○ It is builds upon Google DeepMind's earlier genomics model, **Enformer,** and complements **to AlphaMissense,** which specializes in categorizing the effects of variants within protein-coding regions.
AlphaFold	• Developed by Google DeepMind, predicts a protein's 3D structure from its **amino acid sequence**. • Nobel laureates Demis Hassabis and John Jumper used **AlphaFold2** for predicting protein's complex structures i.e., how proteins **fold into shapes** that determine their functions.
C2S-SCALE (CELL2SENTENCE-SCALE 27B)	• Developed by **Google DeepMind and Yale University** has been designed to **understand the language of individual cells** and interpret complex biological interactions.
Project Suncatcher	• **Launched by Google** to explore **AI computing in space** using solar-powered satellites in low-Earth orbit.
Ironwood	• Google's 7th-generation Tensor Processing Unit (TPU), designed to enhance performance of AI models.

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	• **TPU** is **specialized processor or Application-Specific Integrated Circuit (ASIC)** developed by Google
Jevons and Solow Paradox	• **Jevons and Solow Paradox** were highlighted in the backdrop of increased adoption of the AI systems globally. • **Jevons Paradox:** Technological progress that **makes a resource cheaper** or more efficient to use often **leads to an increase in demand** for that resource. • **Solow Paradox:** Describes the phenomenon where extensive use of advanced technology, such as computers, **does not result in an expected increase in productivity.**

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2.2. QUANTUM TECHNOLOGY

Quantum Technology

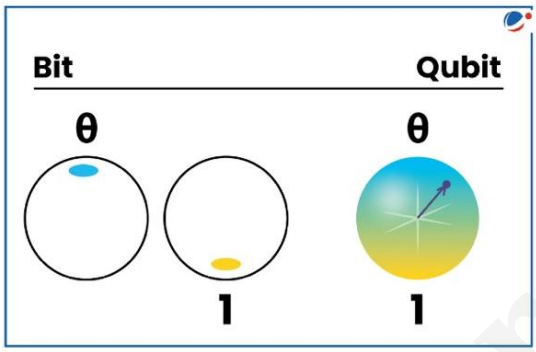
CONCEPT Corner

Quantum Mechanics

- **Quantum mechanics** explains how extremely small objects simultaneously have the characteristics of both **particles** (tiny pieces of matter) and waves (a disturbance or variation that transfers energy).
- A quantum is the smallest possible discrete unit of any physical property.
- German physicist **Werner Heisenberg's** work led to the discovery of **quantum mechanics.**

Qubit and Coherence

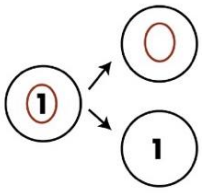
- Quantum Computing uses **qubits** as basic units instead of **binary bits.**
- **Quantum Coherence refers** to the ability of a quantum system to maintain a well-defined phase relationship between different states.



Key Principles of Quantum Technology

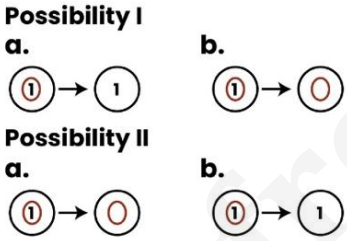
Superposition

- Ability of a quantum particle to be in multiple states at the same time until it is measured.



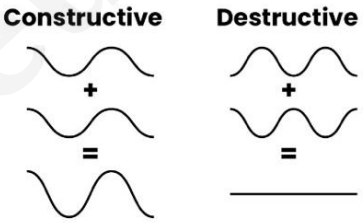
Interference

- Particles can be in more than one place at once, and they can cross their own trajectory to interfere with their path.



Entanglement

- Two particles become linked so that their states are dependent on each other.
- Changes to one particle's state will immediately affect the other particle's state, even if they are far apart.



Key Applications

Simulations: E.g. **In Health care & well-being** (advancing medical imaging and diagnosis) and Quantum chemistry (development of new vaccines and drugs).

Communications: Includes **post-quantum cryptography** (or quantum-proof cryptography) and **Quantum key distribution (QKD).**

Sensing & Metrology: E.g. measurements of forces, gravitation, electric fields, etc.

Material & Devices: Design and synthesis of Quantum Chips (E.g. Google's quantum chip Willow), etc.

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2.2.1. NOBEL PRIZE IN PHYSICS 2025

Why in the News?

John Clarke, Michel H. Devoret and John M. Martinis have been awarded Nobel Prize in Physics for the discovery of **macroscopic quantum mechanical tunnelling** and **energy quantisation** in an electric circuit.

Background

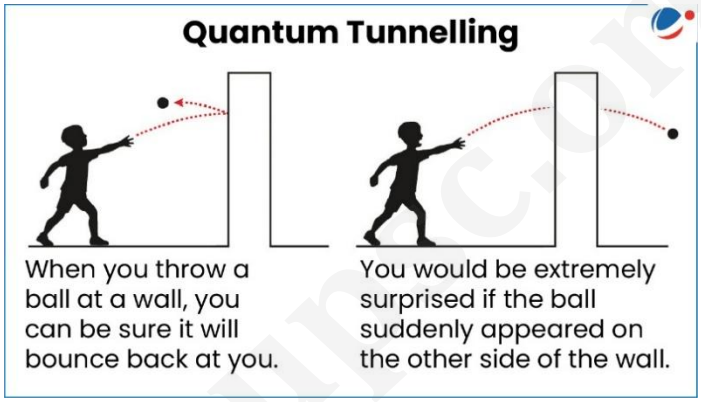
- The quantum effects is prominent at the microscopic level, **vanish at the macroscopic scale** (e.g., in everyday objects like a cricket ball).
- The **2025 Nobel Prize** honors experiments that demonstrated how **quantum phenomena**—such as **quantum tunnelling**—can also be **observed in macroscopic systems**.

Quantisation of Energy

- At the microscopic level, particles **absorb and emit energy in discrete packets**, known as **quanta**.
- Particles such as **atoms, electrons, and protons** can exist only in certain **fixed energy levels**, and not in between.
- This phenomenon is known as the **quantisation of energy**.

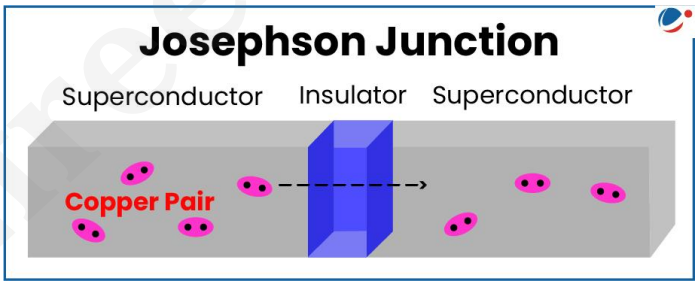
Quantum Tunnelling

- **Quantum physics** reveals a surprising phenomenon: when a **particle encounters a barrier** (a wall of potential energy), there exists a **finite probability** that it may **pass through the barrier** and appear on the other side.
- This strange behavior, known as **quantum tunnelling**, occurred only at the **microscopic scale**.
- A classic example is **radioactive decay**, where part of an atomic nucleus escapes by tunnelling through its potential barrier — as seen in **alpha decay**.



About the Experiment and Result

- John Clarke, Michel Devoret, and John Martinis built an electric circuit using two superconductors separated by an insulator — a **Josephson Junction**.
- They demonstrated that all charged particles in the circuit behaved collectively as a **single quantum particle.**
- They also **demonstrated the quantization of energy in the circuit.**



Significance of the discovery

- Discovery revealed a **macroscopic quantum state**, enabling experiments that apply **quantum phenomena to large-scale systems**.
    - This principle was later used to create **qubits**.
- The work has advanced **quantum technologies** such as **quantum computing,** etc.

2.2.2. QUANTUM KEY DISTRIBUTION (QKD)

Why in the News?

Startup QNu Labs, supported under the **National Quantum Mission (NQM)**, successfully demonstrated India's first extensive QKD network, spanning over 500 kilometers.

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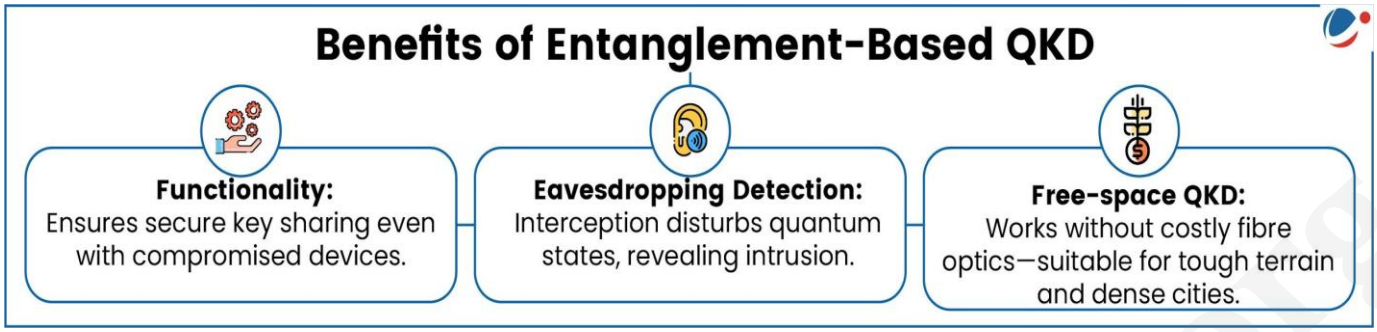
More on the News

- Demonstration involved a network deployed over existing **optical fiber** infrastructure, marking a significant milestone in **quantum-secure communication**.
- It was done under a project funded through the **I-Hub Quantum Technology Foundation,** under the **National Mission on Interdisciplinary Cyber-Physical Systems (NMICPS).**

What is Quantum Key Distribution (QKD)?

- QKD leverages the principles of **quantum mechanics** to ensure secure distribution of the **encryption keys**, used for data communication.
- QKD is an example of **quantum cryptography** (also known as **quantum encryption**).



2.2.3. OTHER DEVELOPMENTS

2.2.3.1. NATIONAL QUANTUM MISSION (NQM)

QpiAI (startup selected under **National Quantum Mission (NQM))** launched **25 qubit superconducting quantum computer (QpiAI-Indus)** on occasion of **World Quantum Day.**

- QpiAI has also developed India's **first quantum computing chip** "25-qubit QPU".

National Quantum Mission (NQM)

- **Aim**: To seed, nurture and scale up scientific and industrial R&D and create a vibrant & innovative ecosystem in Quantum Technology (QT).
- It is one of the nine initiatives under the Prime Minister's Science Technology Innovation Advisory Council (PMSTIAC).
- **Implementing Agency**: Department of Science and Technology
- **Mission objectives**:
  - **Quantum Communication Network**: Establishing a secure and high-bandwidth communication infrastructure spanning 2,000 kilometres.
  - **Quantum Computing Power**: Developing quantum computers with a processing capacity of 1,000 qubits, unlocking immense computational capabilities.
  - **Magnetometry and Atomic Clocks**: Advancing the development of highly sensitive magnetometers for precision measurements and reliable atomic clocks.
  - **Quantum Materials Design**: Synthesizing and characterizing novel quantum materials with tailored properties for cutting-edge device fabrication.
- **Mission also plans to establish four thematic hubs (T-Hubs)**: Quantum computing, Quantum communication, Sensing & metrology, Material & devices.

2.2.3.2. QUANTUM INFORMATION SCRAMBLING

Google quantum processor **"Willow"** outperforms the fastest supercomputers.

- It achieved a ~13,000× speed-up over the best classical algorithms on top supercomputers

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- The team detected "**Quantum Echoes algorithm**" of **scrambled data**, proving information retention through **entanglement**.

About Quantum information Scrambling

- **Definition:** Refers to the rapid spread of information across a quantum system, making it inaccessible to local measurements.
- **Mechanism:** Distributes quantum data among particles through entanglement, hiding information globally rather than erasing it.
  - **Analogy**: Like a **drop of dye dispersing in water**, information initially stored in one qubit gets distributed among many qubits.
- **Significance**: Demonstrates a **verifiable quantum advantage** and enhances understanding of **quantum technologies.**

2.2.3.3. QSIP (QUANTUM RANDOM NUMBER GENERATOR SYSTEM IN PACKAGE)

The Prime Minister dedicated **QSIP** to the nation.

QSIP (Quantum Random Number Generator System in Package)

- It is quantum security chip.
- QSIP provides **quantum-certified randomness** (random numbers from a quantum computer) that is used in cryptographic algorithms.
  - It ensures defence against cyber threats and future quantum attacks.

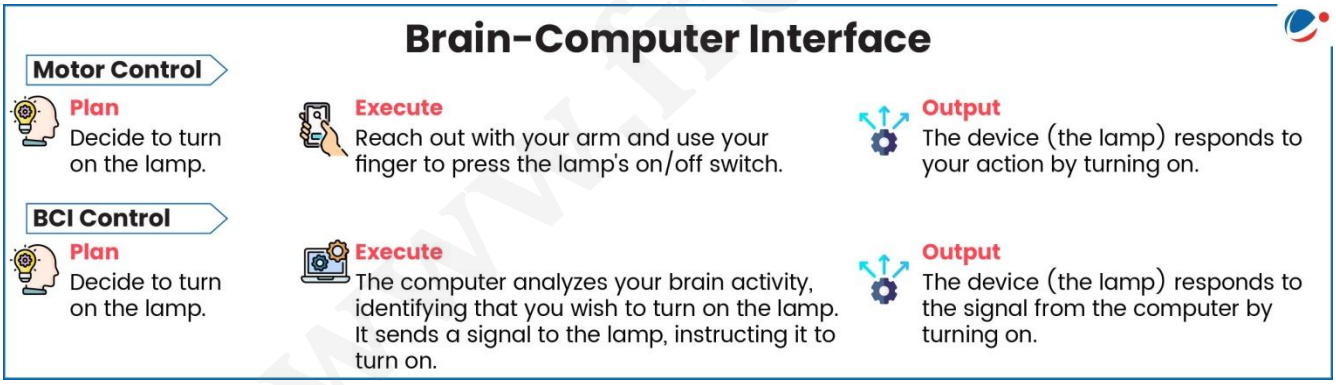
2.3. BRAIN-COMPUTER INTERFACE (BCI)

Why in the News?

Stanford scientists have developed a privacy-focused Brain-Computer Interface that requires a mental password before any thoughts can be decoded into text or audio.

What is a Brain-Computer Interface?

- A BCI enables **direct brain-to-device communication**, translating neural signals into commands.
  - This **bypasses muscular control**, allowing users to operate applications with thought alone.
- BCIs **acquire brain activity (via invasive implants or non-invasive wearables)**, process signals, and send commands, with **feedback crucial for user adaptation.**



Key Applications of BCIs

- **Medical:** Restoring mobility and speech for patients with paralysis, stroke.
- **Mental Wellness:** Providing feedback for mental health management.
- **Gaming/Industry:** Enabling immersive gaming and decision support systems.
- **Cognitive Enhancement:** Potential for enhancing memory, attention, and decision making.

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Related News
Blindsight

- **Neuralink** aims to implant 'Blindsight' chip in first human by **2025**.
- **About Blindsight**
  - A **BCI implant** that aims to **restore vision** by bypassing the retina and directly stimulating the **visual cortex.**
    - **Cortex** is a **region of the cerebral cortex** (**outermost layer of nerve cell tissues**) that is responsible for **processing visual data relayed from the retinas**.
  - **Consists** of **microelectrode array**, embedded in the visual cortex, capable of stimulating neurons or nerve cells.

2.4. 3D PRINTING

Why in the News?

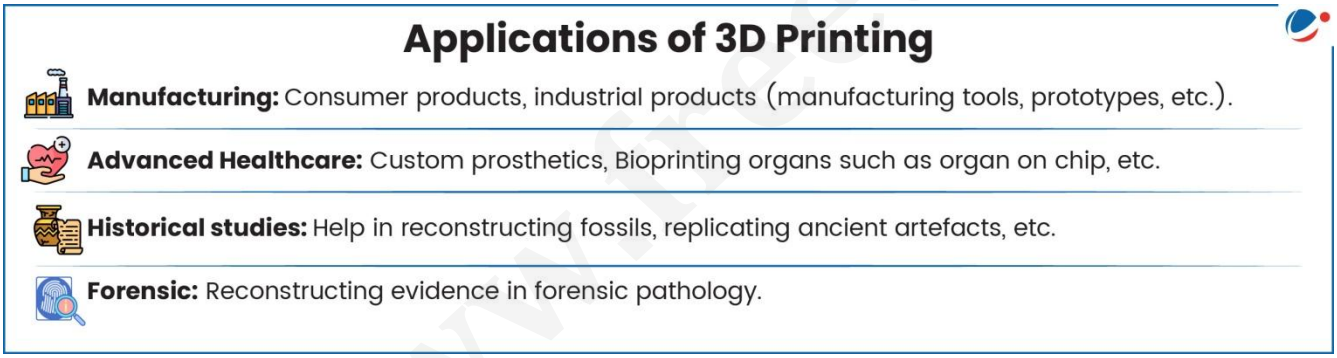
Japan built 3D-Printed Train Station in just 6 Hours**.**

About 3D Printing

- 3D printing or **additive manufacturing** is a process of making three-dimensional objects from a digital file.
- **Process:** 3D-printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the object is created.

Advantages of 3D Printing

- **Immediate realization of concepts:** As soon as designers have a 3D model possible to bring design to life.
- **Less dependency on workforce:** Significant for countries like Japan where the workforce is shrinking.
- **Customization on demand**: It can be done very quickly without altering the entire manufacturing process.
- **Cost-Effective**: Savings on material costs, labour and operational efficiency, reduced inventory and warehousing costs, etc.
- **More design freedom**: Complex geometries and lattices can be incorporated.
- **Other:** Eco-Friendly and sustainable, supports on-demand and on-location production, ensures better quality products, etc.



4D Printing

- Evolved from **3D printing** by adding the dimension of time.
- In it, objects can change shape or function over time in **response** to **environmental stimuli** such as heat, light, or moisture, etc.

2.5. STABLECOINS

Why in the News?

The GENIUS Act has been enacted in the US to establish a **regulatory framework** for **stablecoins.**

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About Stablecoins

- Stablecoins are a type of **cryptocurrency** whose value is linked to that of another **currency**, **commodity**, or financial instrument. E.g., **Tether (USDT)**, is pegged to the US dollar.
- They have the potential to **bring efficiencies** to **payments.**
- **There are primarily three types of stablecoins:** fiat-collateralized, crypto-collateralized, and non-collateralized (algorithmic).
- **Concerns:** Risk of mass withdrawal of holdings simultaneously, fail the test of elasticity (cannot expand quickly to provide additional liquidity in case of high demand), risk of money laundering, etc.

Regulation of Cryptocurrency or Crypto Assets in India

- Currently, **Crypto Assets are unregulated in India.**
- However, **Government,** through the **Finance Act, 2022,** brought a comprehensive taxation regime **for the transfer** of **Virtual Digital Assets (VDAs).**
  - It imposed a **30% tax** on **capital gains** from **VDAs.**
  - The **Income Tax Act 1961** defines **VDA** as any information or code or number or token, generated through **cryptographic** means or otherwise; transferred, stored, or traded electronically. E.g. cryptocurrencies, Non-fungible token (NFT), etc.
- In 2023, VDAs were brought under the purview of the **Prevention and Money-laundering Act, 2002**.

2.5.1. CENTRAL BANK DIGITAL CURRENCY (CBDC)

Why in the News?

RBI Governor suggested other central banks to promote **Central Bank Digital Currency (CBDC**) over stablecoin.

About Central Bank Digital Currency (CBDC)

- CBDC is a new form of money that exists only in digital form.
  - Instead of printing money, the **central bank issues** widely accessible digital coins so that digital transactions and transfers become simple.

Why does CBDC need to be preferred over Stablecoin?

- **Sovereign Backing: CBDC** are considered legal tender, i.e. they are recognised and accepted by the government for every transaction.
  - CBDCs operate within a **regulated framework**, ensuring consumer protection, etc. unlike many stablecoins which lack regulatory oversight.
- **Cross-Border Payment Efficiency:** CBDCs can simplify and speed up international trade payments, reducing reliance on intermediaries like SWIFT.

CBDC in India

- **Digital Rupee** is India's CBDC.
- Issued by the RBI in digital form and offers features similar to physical cash like convenience of use, guarantee of RBI, finality of settlement, etc.
- **Stored** in the user's **digital wallet** and can be used to receive / send money, and / or make payment for transactions, just like any physical ₹ note.

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- The RBI is currently conducting pilot projects of two types of CBDCs – retail and wholesale.
  - **Retail CBDC:** It is available to the general public via digital wallets, smartphone apps, etc.
  - **Wholesale CBDCs:** Used among banks and other licensed financial institutions for interbank payments and securities transactions.

2.6. OTHER IMPORTANT NEWS

2.6.1. BLUETOOTH MESH NETWORKING

Twitter Co-Founder shared details of Bluetooth Messaging App, Bitchat.

- Bitchat relies on **Bluetooth Low Energy Mesh Networking** to **enable communication**

What is Bluetooth Mesh Networking?

- Relies on **Bluetooth clusters** or **Mesh network** created by devices in a range.
- **Mesh network**, also known as "**multi-hop network**", is a networking topology.
  - In it, **data can travel from any device** to all others, achieving **many-to-many communication**.
  - Even if one device fails, the network keeps working.
- Messages are broadcast and relayed by **nodes** until they reach the **intended destination**.
- **Potential Benefits:**
  - **No central database**: **Messages** are **stored entirely** on users' devices and are deleted after a short period. This design is created to **priorities users' privacy**.
    - Also, Messages are **end-to-end encrypted** and do not leave the network.
  - **No registration required**: Users are not required to create accounts using their email or phone number, making the communication anonymous.

2.6.2. PROJECT WATERWORTH

Meta has selected Mumbai and Visakhapatnam as the landing sites for the undersea cable **project**, **Waterworth**.

- It will connect five major continents. It is the world's longest subsea cable project.

About Undersea Cables

- Undersea cables are **fiber-optic cable laid across the ocean floor** that transmits information and enables worldwide communications.
- **Significance:** Undersea **cables are** backbone of international internet.

2.6.3. VIKRAM3201

India's first 32-bit processor – Vikram3201 – presented to the PM at Semicon India 2025.

About Vikram3201 Processor

- An **advanced version of the indigenously designed 16-bit VIKRAM1601** microprocessor which has been flying in the Avionics system of ISRO's launch vehicles.
- Fully **"Make-in-India" 32-bit microprocessor** qualified for the **harsh environmental conditions of launch vehicles**.
- Designed and developed by the **Vikram Sarabhai Space Centre of ISRO** in collaboration with the Semiconductor Laboratory (SCL) in Chandigarh.
  - They have also developed **KALPANA3201**, another 32-bit microprocessor.

2.6.4. FASTAG

Ministry of Road Transport and Highways launched FASTag Annual Pass facility.

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About FASTAG

- A device that **employs Radio Frequency Identification (RFID) technology** for making toll payments directly from account while the vehicle is in motion.
  - **RFID consists** of tags and readers and employs radio waves to communicate information of objects or people to nearby readers.
  - It is a **short-range technology**.
- **Affixed on the windscreen of the vehicle** and enables a customer to make the toll payments directly from the account which is linked to FASTag.
- **Developed by**: NPCI under National Electronic Toll Collection (NETC) program.

2.6.5. DIGITAL TWIN

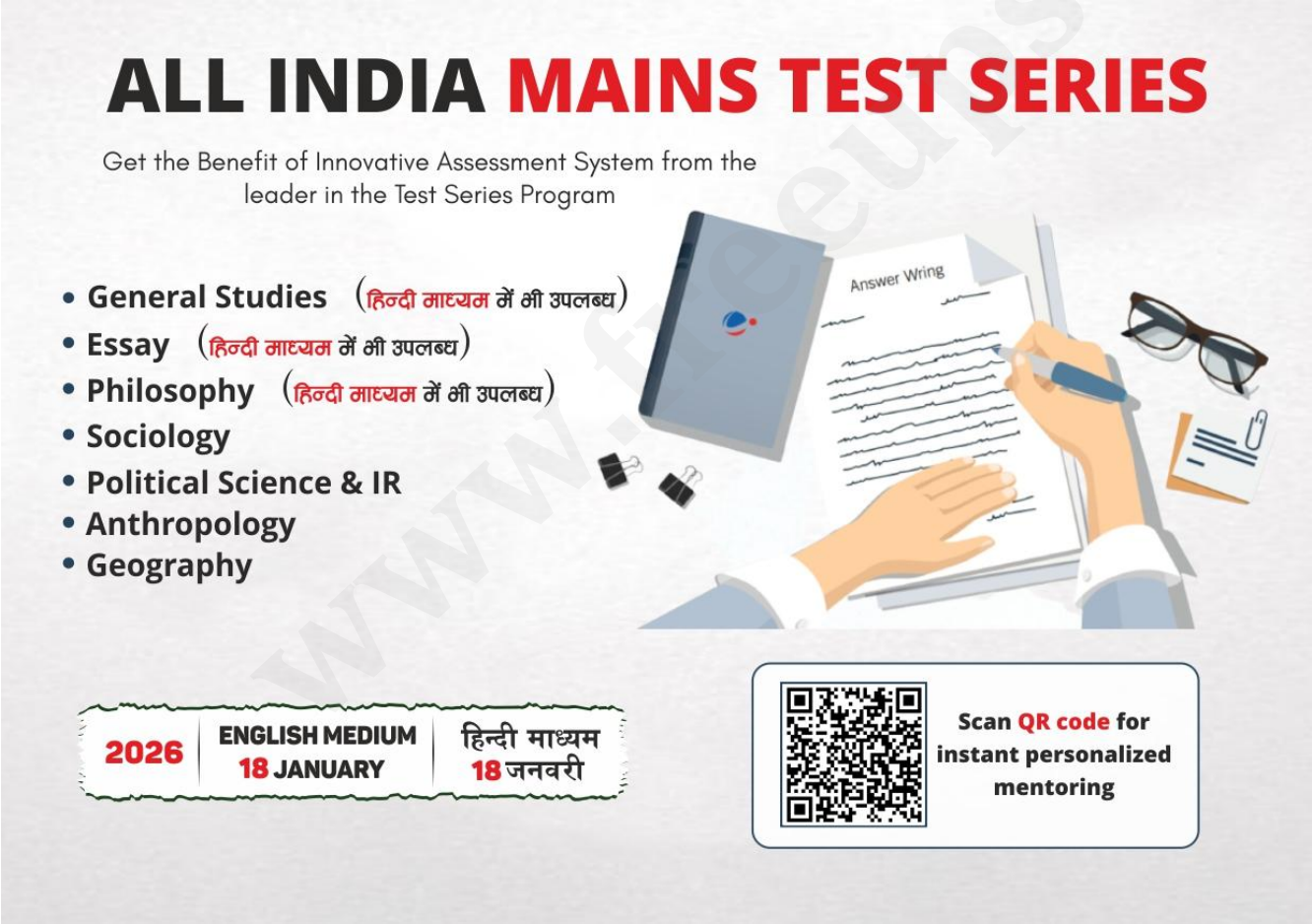
- A digital twin is a digital representation of a **physical object**, person, or process, contextualized in a digital version of its environment.
- It can help an organization simulate real situations and their outcomes, ultimately allowing it to make better decisions.
- It uses **real-time data** from **sensors** for behavior simulation and operation monitoring.

2.6.6. SSI MANTRA

SSI Mantra performed world's first cardiac telesurgery across 10,000 km

About SSI Mantra

- India's indigenous surgical robotic system.
- **Key features**: 3D High-Definition Visualization, Predictive Analytics, etc.



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3. DEVELOPMENT RELATED WITH PHYSICS

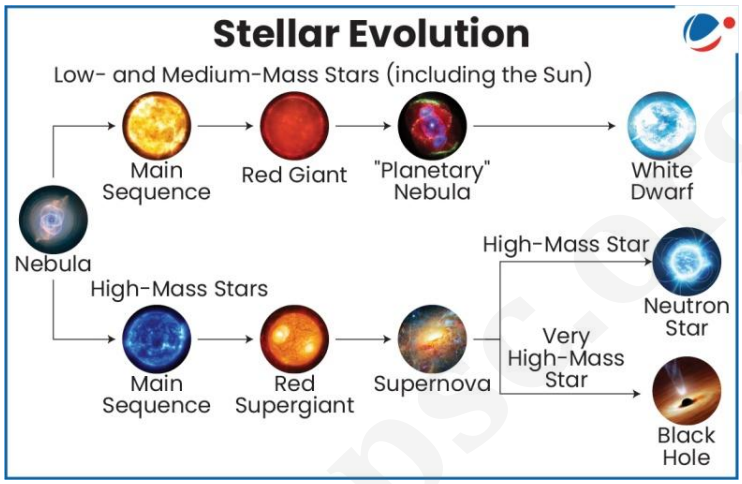
3.1. BLACK HOLE MERGER

Why in the News?

An international network of gravitational wave observatories has recently detected the **merger of two exceptionally massive black holes.**

More on the News

- Two black holes **merged** to form a black hole estimated to be about 225 times the size of the Sun.
  - This is the **biggest black hole merger ever observed**.
- The detection of the **gravitational waves** (assigned name is **GW231123)** from this event was made **by the LVK network of observatories**, involving the **LIGO detector** in the United States, **Virgo** in Italy and **KAGRA** in Japan.

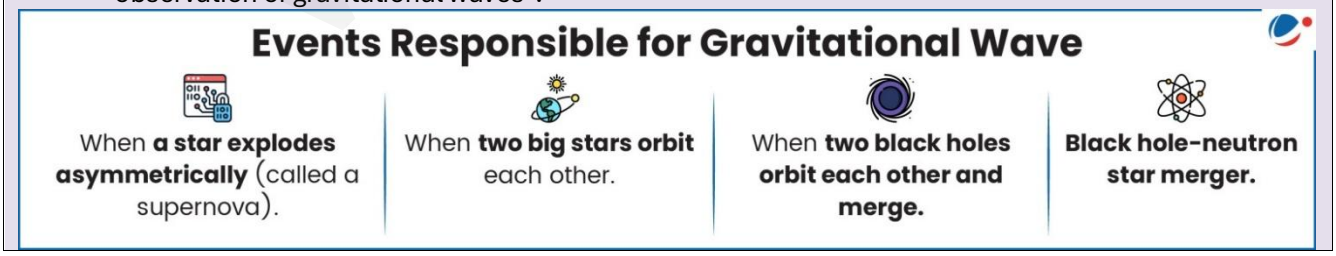


Black Holes

- A place in space **where gravity pulls so much that even light cannot get out**. The gravity is so strong because matter has been squeezed into a tiny space.
- **Black holes don't emit or reflect light,** making them effectively invisible to telescopes.
  - However, scientists can see how the strong gravity affects the stars and gas around the black hole.
- **Formation of Black Hole**: Most of black holes are formed from the remnants of a **large star** that dies in a supernova explosion.
  - When stars are especially large, the core collapses into a black hole. Otherwise, the core becomes an ultra-dense neutron star.
- **Types of Black Holes:**
  - Stellar-Mass Black Holes
  - Intermediate-Mass Black Holes (IMBH)
  - Supermassive Black Holes

Gravitational Waves

- **These** are **'ripples' in space-time** caused by some of most violent and energetic processes in the Universe.
- Predicted in **Einstein's General Theory of Relativity.**
- Travel at the speed of light.
- They permeate the universe at high frequency creating a **cosmic hum**.
- **GWs' first detection:** Detected at the Laser Interferometer Gravitational-Wave Observatory (LIGO) in 2015.
  - 2017 Nobel Prize in Physics was awarded" for decisive contributions to the **LIGO detector** and the observation of gravitational waves".



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- **Gravitational Wave Detection Network**
  - **Laser Interferometer Gravitational-wave Observatory-LIGO:** Supported by the U.S. National Science Foundation (NSF), world's largest gravitational wave observatory.
    - Currently, has two detectors in Hanford, Washington and Livingston Louisiana.
    - LIGO-India is to be developed in Hingoli, Maharashtra by the **Department of Atomic Energy and the Department of Science and Technology,** with the U.S. NSF and several national and international research institutions.
  - **Virgo, in Pisa, Italy:** Hosted by European Gravitational Observatory (EGO), a collaboration of Italy and France.
  - **KAGRA, Japan:** Located inside the Kamioka mine.

3.2. NEUTRINO

Why in the News?

World's largest Neutrino detector '**Jiangmen Underground Neutrino Observatory or JUNO**' is activated in China.

More on the News

- The observatory is situated **700 meters underground.**
  - Most of the neutrino observatories are underground, as the physical bulk of the Earth's crust helps **block most other interfering particles**, like muons.
- **Key goals of the JUNO**
  - **Mass Hierarchy:** To determine the hierarchy of masses between the three neutrino types.
  - The three neutrino types are **Electron neutrino, Muon neutrino, and Tau neutrino**.
    - **Muon (similar to electrons)** is one of the fundamental subatomic particles, the most basic building blocks of the universe as described in the **Standard Model of particle physics**.
  - **Oscillation Frequency:** To measure the frequency of neutrino oscillation.

About Neutrinos

- **Nature:** Subatomic particles (often called **ghost particles)** that have zero electrical charge, zero size and tiny mass.
- **Occurrence: Second-most abundant particle** after **photons** (particles of light) and most abundant among particles found in the universe.
- **Detectability:** Difficult to detect as they only interact with matter via **weak nuclear force** and **gravity.**
- **Features:** Undisturbed by even the strongest magnetic field, travel in straight lines from their source, Travel at nearly the speed of light, etc.

Key Neutrino Observatories

- **Karlsruhe Tritium Neutrino (KATRIN)** Experiment, located in Germany.
- **India-based Neutrino Observatory (INO):** Funded by DAE & DST; located in Bodi West Hills, Tamil Nadu.
- **IceCube Neutrino Observatory:** First deep-ice cosmic neutrino detector at the South Pole.
- **Other: Tropical Deep-sea Neutrino Telescope (TRIDENT) and Deep Underground Neutrino Experiment (DUNE):** China and USA projects, respectively.

3.3. CERN (EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH)

Why in the News?

Experimental High Energy Physics group of **Bose Institute (BI)** has been awarded the **Breakthrough Prize 2025 in Fundamental Physics** as a part of ALICE at CERN.

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More on the News

- **Breakthrough Prize 2025** is awarded to **researchers from more than 70 countries** representing four experimental collaborations at **CERN's Large Hadron Collider (LHC).**
- It has been awarded for discovery of **new strongly interacting particles**, study of rare processes and **matter-antimatter asymmetry**, etc.

About CERN (European Organization for Nuclear Research)

- An international scientific organization established for the purpose of collaborative research into **high-energy particle physics**.
- **Location**: Franco-Swiss border
- **India** is an Associate Member.
- **Major Achievements**
  - LHC confirmed the existence of the **Higgs boson** (Also, known as God particle)**.**
    - Higgs Boson is a subatomic particle that was first theorized by physicist Peter Higgs and others.
  - Development of the **World Wide Web**

About CERN's LHC

- **World's largest** and **most powerful particle accelerator.**
- Consists **of superconducting magnets** with a number of **accelerating structures** to boost the energy of the particles along the way.
  - Inside the accelerator, **two high-energy particle** beams travel at close to the **speed of light** before they are **made to collide.**

Matter–Antimatter Asymmetry

- A major milestone in understanding the **matter-antimatter asymmetry** in the universe as CERN's scientists has observed **CP violation** in **baryons** for the **first time**.
  - **CP symmetry** implies laws of physics should remain unchanged if particles are swapped with their antiparticles and viewed in a mirror.
- **About Matter–Antimatter Asymmetry**
  - Refers to the observed imbalance between matter and antimatter in the universe.
  - According to modern physics, the Big Bang **should have produced equal amounts** of matter and antimatter, yet the observable universe **consists almost entirely of matter**, with antimatter nearly absent.
    - If they come in contact, they annihilate one another, leaving behind pure energy.

3.4. ORDINARY MATTER

Why in the News?

Harvard & Smithsonian (CfA) and Caltech, **for the first time**, detected the universe's **missing ordinary matter** using powerful **cosmic signals known** as **Fast Radio Bursts (FRBs).**

Distribution of Ordinary Matter Across the Universe

- 76% in **intergalactic medium (IGM)** (the thin gas between galaxies).
- 15% in galaxy halos (outer regions surrounding galaxies)
- 9% within galaxies (consist of stars, planets, and vast clouds of gas and dust, all bound together by gravity).

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Ordinary Matter (baryonic matter) Vs. Dark Matter

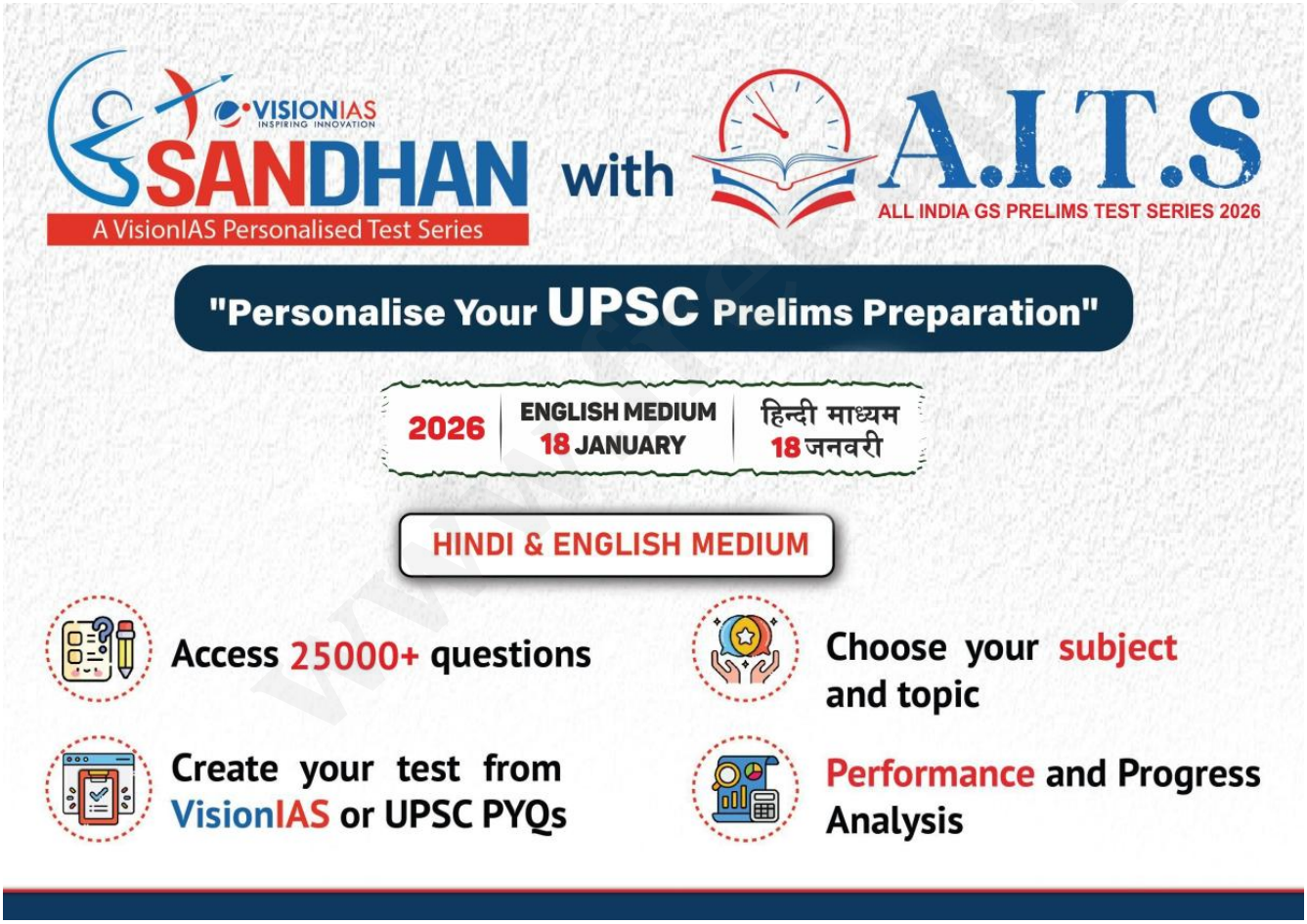
- **Ordinary Matter includes**: Gas, Dust, Stars, Planets & Everyday substances (like water), **that does interact** with electromagnetic radiation (i.e., **light).**
  - Unlike dark matter, ordinary matter is composed of **baryons (**include protons, neutrons)
- **Dark Matter:** It makes up about 27% of the cosmos but remains invisible because **it doesn't interact with light.**
  - Dark matter interacts **very weakly or almost not at all** with the ordinary matter.
- **Similarities:**
  - Both are matter, meaning they have **mass** and **take up space.**
  - Both **exert gravitational force.**

About Fast Radio Bursts (FRBs)

- **Definition:** FRBs are blasts of **electromagnetic radiation** in the form of **radio waves** usually emanating from **galaxies beyond our own.**
- FRBs have durations ranging **from milliseconds to just a few seconds.**

How Fast Radio Bursts (FRBs) Helped Solve the Mystery?

- **FRBs acted as "cosmic flashlights"**. As FRBs travel through space, they:
  - **Disperse into different wavelengths**, like a prism spreading sunlight.
  - **The degree of dispersion** reveals the **amount of matter** in their path.
- **FRBs provided** the **first direct measurement** of matter distribution across the **cosmic web** & established themselves as a reliable **cosmological probe.**



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4. SPACE TECHNOLOGY

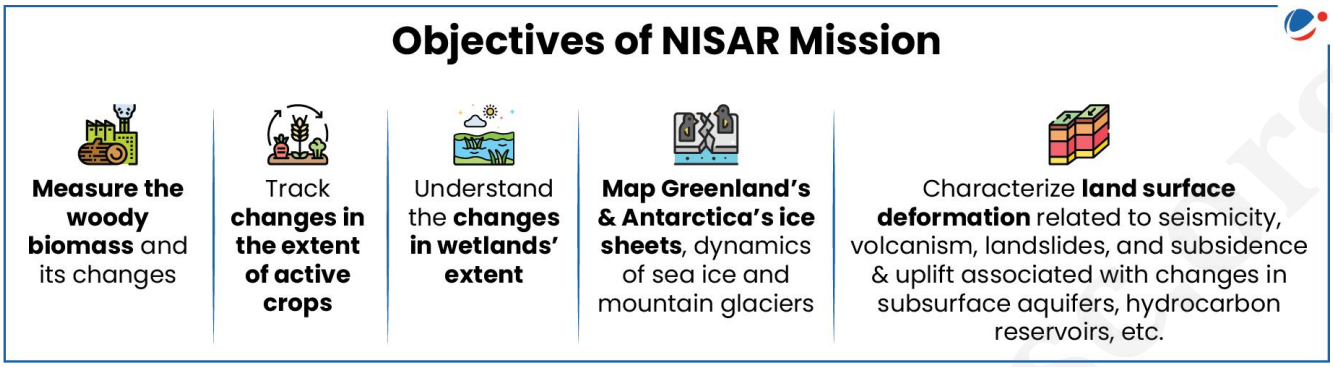
4.1. NISAR (NASA-ISRO SYNTHETIC APERTURE RADAR) SATELLITE

Why in the News?

After the successful launch of NASA-ISRO Synthetic Aperture Radar (NISAR) satellite in July 2025, the 12m diameter Antenna reflector has been successfully deployed.

About NISAR Mission

- NISAR is a global, **microwave imaging mission, with capability to acquire fully polarimetric and interferometric data.**
  - It is world's **first Earth observation satellite to integrate both L-band** and **S-band Synthetic Aperture Radar (SAR)** on a single platform.



- **NASA provided** the L-band radar, GPS receiver, high-rate telecom system, etc.
- **ISRO contributed** the S-band radar, the spacecraft bus, etc.
- **Launch Vehicle:** ISRO's Geosynchronous Satellite Launch Vehicle (GSLV)-F16.
  - It was launched from **Satish Dhawan Space Centre, Sriharikota.**
- **Orbit: Sun Synchronous Polar Orbit**
  - It is the **first time a GSLV rocket was used to place a satellite into a Sun-Synchronous orbit (SSO).**
  - **GSLV is** typically used for placement in **Geosynchronous Transfer Orbit/GTO**.
- **Mission Life:** 5 years

Technical Features

- **SweepSAR (Swept Synthetic Aperture Radar)**: Produces high-resolution, wide-swath images across a broad range of terrain.
  - In SAR, an instrument **sends out a pulse of energy** and then **records the amount of that energy reflected back after it interacts with Earth**.
- **Repeat Cycle:** Provides **high-resolution data every 12 days** to monitor land changes across Earth.
- **Antenna and Resolution:** The satellite features a large, 12-metre diameter common unfurlable reflector antenna.
- **Open-Data Policy:** Information collected will be freely available to global scientific community.

4.2. GAGANYAAN MISSION

Why in the News?

ISRO successfully completes first Integrated Air Drop Test for Gaganyaan Mission.

More on the News

- Its objective was to validate the parachute system **that will bring back astronauts safely under the Gaganyaan mission.**

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Gaganyaan Programme

- **About:** It will be **India's first Human Space Flight** mission.
- **Aim**: Demonstration of **human spaceflight** capability by launching a crew of **3 members** to an **orbit of 400 km (LEO)** for a 3-day mission and bring them back safely to earth.
  - Gaganyatri will carry out shortlisted Indian microgravity research experiments onboard ISS.
- **Components of the Gaganyaan**
  - **Launch Vehicle Mark-3 (LVM-3):** Formerly known as GSLV Mk-III, it is a 3-stage rocket:
  - **Orbital module**: Consisting of Crew Module and Service Module.
- AI-powered **Gynoid (female robot) Vyommitra** (half-humanoid) will undertake the first **uncrewed mission of Gaganyaan.**
- The **scope** of the Programme has been **extended** to include building of **first unit of the Bharatiya Antariksh Station.**
- Successful launch of Gaganyaan **will make India only the 4th country** (after the US, Russia, and China) that have launched crewed spacecraft.

Bharatiya Antariksh Station (BAS)

- BAS is India's **planned space station for scientific research**
- It will orbit around **400 – 450km** above the Earth's surface. It will have **five modules.**
- **Significance:** Serves as a testing ground for studying how to keep astronauts safe and healthy on long-duration missions, facilitating microgravity research, etc.

4.3. ADITYA-L1 MISSION

Why in the News?

Using data from the **Visible Emission Line Coronagraph (VELC)** onboard Aditya-L1, scientists from the Indian Institute of Astrophysics (IIA), in collaboration with NASA, have successfully estimated key parameters of a Coronal Mass Ejection (CME).

About Aditya-L1 Mission

- **India's first** dedicated **solar mission.**
- **Objectives**: To understand Coronal Heating and Solar Wind Acceleration; flares and near-earth space weather; Solar wind distribution and temperature anisotropy etc.
- **Lifespan**: 5 years
- **7 payloads**:
  - **Remote Sensing Payloads**: VELC, Solar Ultraviolet Imaging Telescope (SUIT), etc.
  - **In-situ Payloads:** Aditya Solar wind Particle Experiment (ASPEX), etc.
- It placed in a **halo orbit** around the **Lagrange point 1 (L1)** of the Sun-Earth system, which is about 1.5 million km from the Earth.
  - **Halo orbit** is a periodic, three-dimensional orbit at L1 involving Sun, Earth and a spacecraft.
  - At **Lagrange points**, the **gravitational pull** of two **large masses precisely equals the centripetal force required** for a **small object to move with them**.
    - These points allow continuous, uninterrupted observation of the Sun. Also, they help in reducing fuel consumption.

Other Major Solar Missions

- **Hinotori (ASTRO-A)** launched by Japan.
- **Parker Solar Probe** launched by US (first spacecraft to fly through the corona-the Sun's upper atmosphere)

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- **Solar and Heliospheric Observatory Satellite (SOHO)** mission launched jointly by NASA-ESA (longest-lived Sun-watching satellite).

4.4. SPADEX MISSION

Why in the News?

ISRO achieved second successful satellite docking under SpaDeX Mission.

More on the News

- **The docking technology** (joining of two fast-moving satellites in space)**,** indigenously developed by ISRO, is known as the **Bhartiya Docking System.**
- **In-space docking technology** is essential when multiple rocket launches are required to achieve common mission objectives.

About SpaDeX Mission

- **Objective:** To develop and demonstrate the technology needed for **rendezvous, docking, and undocking** of two small spacecraft (**SDX01** (Chaser) and **SDX02** (Target)) in a **low-Earth circular orbit.**
- **SpaDeX spacecraft** were designed and realized by the **UR Rao Satellite Centre (URSC)** with the support of other ISRO centers.
  - URSC, Bengaluru, formerly known as ISRO Satellite Centre (ISAC) is the lead centre for building satellites and developing associated satellite technologies.

Significance of the Mission

- **Strategic Space Capability:** Orbital docking is a crucial technology for **future human spaceflight**, **satellite servicing missions**, and establishing **Bharatiya Antariksh Station.**
- **National Advancement:** The mission made **India the fourth country in the world to achieve satellite docking in space**, joining the ranks of the US, Russia, and China.

4.5. CHANDRAYAAN-3

Why in the News?

Chandra's Surface Thermophysical Experiment (ChaSTE) of **Chandrayaan-3** became the first mission to successfully penetrate the soil of a celestial body to deploy a thermal probe.

About Chandrayaan-3

- A **follow-on mission** to Chandrayaan-2.
- Became the world's **first mission** to soft-land near the lunar South Pole.
  - The landing site was named as **'Shiv Shakti' point** (Statio Shiv Shakti).
  - Soft-landing was followed by the successful deployment of **Pragyan Rover**.
- India became the **fourth country** to soft land on the moon, after the US, Russia, and China.
  - Recently, Japan became the fifth country to land its **Smart Lander for Investigating Moon (SLIM)** on the Moon.
- **Launch vehicle**: Geosynchronous Satellite Launch Vehicle Mk III.
- **Key Payload**: Alpha Particle X-ray Spectrometer (APXS), Laser Induced Breakdown Spectroscope (LIBS), etc.

Related News

GRAIL (Gravity Recovery and Interior Laboratory) Mission

- **NASA's GRAIL Mission** created the most detailed map of the Moon's gravity.
  - GRAIL Mission was as a part of **NASA Discovery Program.**
- **Key findings of the mission**
  - **Uneven Moon Interior:** The Moon's **nearside** (facing Earth) is **warmer and more geologically active** than the **farside**.

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- **Tidal Deformation:** Earth's gravity causes the **nearside to flex more** than the farside during the Moon's orbit. This flexing shows **structural differences** between the two sides of the Moon.

- **About the far side of the Moon**
  - Refers to the **hemisphere of the Moon that always faces away from Earth (hence** also referred to as the dark side of the Moon).
    - This happens because the **Moon is tidally locked with Earth** due to gravitational pull.
  - It has a **thicker crust, more craters, and fewer lava plains** than near side**.**
  - **Reaching the Moon's far side is challenging** due to its remoteness and rugged landscape, featuring massive craters and limited flat areas.

4.6. AXIOM-4 MISSION

Why in the News?

The **Axiom-4 Mission** carrying **Indian astronaut** Group Captain **Shubhanshu Shukla** and 3 other astronauts successfully returned on July 15, 2025.

About Axiom-4 (Ax-4) Mission

- Ax-4 is a **4th private astronaut mission,** to the **International Space Station (ISS),** of private US Company **Axiom Space** in collaboration with **NASA** and **SpaceX.**
  - It was launched aboard a **SpaceX Dragon Spacecraft** by the **Falcon 9 launch vehicle**.
- **Aim**: To "realize the return" to human spaceflight for **India, Poland, and Hungary.**
  - **Ax-4** marks each nation's **first mission to the ISS** (except USA) in history and with **each nation's first government-sponsored flight** in more than 40 years**.**
- **Shubhanshu Shukla** is the **first** Indian astronaut to board the ISS and only the **second Indian** to travel to space after **Rakesh Sharma** in **1984**.

Key Research and activities executed by ISRO

- **Crop growth:** Study impact of microgravity on 6 crop seed varieties for future space farming.t
- **Cyanobacteria:** Observe growth and activity for use in spacecraft life support systems.
  - Cyanobacteria are **aquatic bacteria** that can **photosynthesize.**
- **Space Microalgae:** Compare metabolic and genetic activity in space vs Earth; potential use as food, fuel, or for life support.
- **Myogenesis:** Study muscle loss, identify pathways responsible for **skeletal muscle** dysfunction in microgravity and explore therapeutic targeting strategies.
- **Tardigrades:** Investigate the revival, survival, and reproduction of **tardigrades** (commonly known as **water bears**) to identify molecular mechanisms of resilience.

About International Space Station (ISS)

- A **habitable artificial satellite** in Low Earth orbit (LEO).
- **Key partners for ISS**: Europe (ESA), the USA (NASA), Japan (JAXA), Canada (CSA) and Russia (Roscosmos)
- **Largest artificial body in orbit** providing a **laboratory in space**, having an orbit such that it can fly over **90% of inhabited Earth.**

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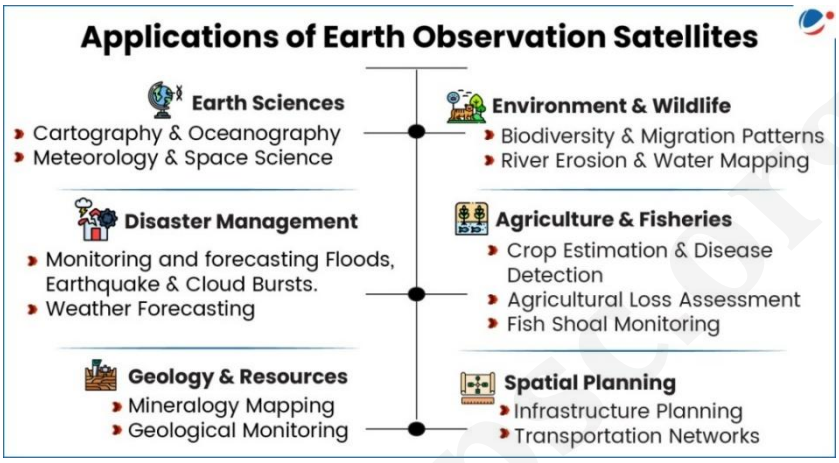
4.7. COMMERCIAL EARTH OBSERVATION (EO) SATELLITE CONSTELLATION

Why in the News?

Pixxel successfully launched three new **Firefly satellites** aboard the SpaceX NAOS Falcon 9 mission completing the first phase of its commercial constellation.

More on the News

- **PixxelSpace India-led Consortium** has **won the IN-SPACe proposal to build India's first** fully indigenous commercial **Earth Observation Satellite System** (EOSS) under PPP model.
  - **PixxelSpace India consortium** comprises Piersight Space, Satsure Analytics India, and Dhruva Space.
  - **Public-Private Partnership (EO-PPP) model**: The private sector will design, build, and operate the EOSS while, the government will provide strategic, technical, and policy support.
- **Also, LEAP-1 mission of Dhruva** Space's, hosting two In-Orbit Demonstration (IOD) missions, was launched aboard the SpaceX NAOS Falcon 9 mission.



About the proposed Earth Observation Satellite System (EOSS)

- **A constellation of 12 state-of-the-art EO satellites** planned to be launched over the **next 5 years.**
  - It will be equipped with panchromatic, multispectral, **hyperspectral**, and microwave **SAR sensors**.
- **Deployment period:** Four years

About EO Satellites

- Also called as **Earth remote sensing satellites.**
- **They are designed to collect** information about activities on Earth, both natural and artificial, including physical, chemical, biological and human systems.

4.8. EARTH'S POLAR ORBIT

Why in the News?

Mission titled **"Fram2"** has been launched using Dragon spacecraft of SpaceX.

More on the News

- It will carry out a series of experiments, including the **first X-ray in space and the cultivation of mushrooms in microgravity.**
- It will be the first human spaceflight to **cruise directly** over **Earth's Polar Regions.**

About Earth's polar orbit

- A polar orbit is when a satellite orbits Earth by **passing over the** North **and South Poles.**
  - A deviation of **10 degrees over north and south poles** is still classified as a **polar orbit.**
- **Height:** Polar orbits are a **type of low Earth orbit**, typically between 200 to 1000 km in altitude.
- **Significance:** A spacecraft orbiting over the poles can **observe the entire planet as it spins underneath.**
  - The path is particularly **useful for weather, mapping and spy satellites.**
- **Issue:** Launching rocket into polar orbits **requires greater fuel** since rockets cannot harness Earth's rotational speed.

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Satellite Orbit	Altitude	Application	Details
Low Earth orbit (LEO)	**Under altitudes of 2000 km**	Satellite imaging, communication, Earth observation, navigation and scientific research.	International Space Station (ISS) also orbits here as shorter distance makes it easier for astronauts to reach.
Sun-synchronous orbit (SSO)	**Between 600 to 800 km**	Ideal for studying land-use changes, ice melting, and weather.	Particular kind of polar orbit in which satellites are in sync with Sun.
Medium Earth orbit (MEO)	**From 2,000 to 36,000 kilometers**	Ideal for navigation satellites and telephone communications.	Satellites in MEO do not need to follow specific paths around Earth.
Geostationary orbit (GEO)	**35,786 km**	Telecommunication, weather satellites, GPS etc.	Fly above Earth's equator, moving from west to east, exactly matching Earth's rotation.

4.9. OTHER SPACE MISSIONS/SATELLITES IN NEWS

4.9.1. ISRO MISSIONS

Mission/Satellite	Key Details
Astrosat	» India's first dedicated astronomy mission. » **Objective:** Designed to study celestial objects across X-ray, ultraviolet, and **optical wavelengths simultaneously,** offering a holistic view of cosmic phenomena. » **Orbit:** Placed in **a low Earth orbit.** » **Spectral Range:** Covers near and far UV regions, enabling exploration of **both high-energy** and **faint astronomical sources.**
Venus Orbiter Mission (VOM)	» India's proposed mission to Venus. » **Objectives:** Examine dust in the Venusian atmosphere and its airglow, map its surface topography, study solar X-ray spectrum, and investigate sub-surface characteristics. » **Launch Vehicle:** Launch Vehicle Mark-3 (LVM-3) » **Key Payloads:** Venus Advanced Radar for Topside Ionosphere and Subsurface Sounding (VARTISS), Venus Orbit Dust Experiment (VODEX), etc.
XPoSat (X-ray Polarimeter Satellite)	» First dedicated satellite from ISRO to carry out research and measure X-ray emission from celestial sources like black holes and neutron stars. » It is Second satellite in the world to study X-ray polarization, first being NASA's Imaging X-ray Polarimetry Explorer (IXPE). » **XPoSat payloads:** POLIX (Polarimeter Instrument in X-rays) and XSPECT (X-ray Spectroscopy and Timing). » **Spectroscopy** is the study of the interaction between the electromagnetic radiation and matter.
Aryabhata Satellite	» **India's first satellite,** Aryabhata, completed **50 years.** » **Orbit:** Low Earth Orbit. » Built to conduct experiments in **X-ray astronomy, aeronomics, and solar physics.** » Named after the **ancient Indian mathematician and astronomer.**

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4.9.2. OTHER AGENCIES

Mission	Agency/Country	Key Details/Features
Lucy Mission	NASA	➤ Launched in 2021, the name Lucy was chosen in honor of the **fossilized human ancestor,** named **Lucy.** ➤ **Objective:** First space mission to explore **Jupiter Trojan asteroids** (remnants from the early solar system). ➤ **Trojan asteroids** orbit in two "swarms" that lead and follow Jupiter.
Tianwen-2 probe	China National Space Administration (CNSA)	➤ **Objective:** Collect samples from the **asteroid 2016HO3** and explore the **main-belt comet 311P.**
Biomass Mission	European Space Agency (ESA)	➤ Biomass is the **first satellite to carry a P-band SAR.** ➤ **Objective:** Map the **world's forests** to provide the **first comprehensive measurements of forest** biomass and stored carbon at a global scale.
Solar Orbiter	ESA & NASA	➤ **Objective:** To take **close-up images** of the Sun, observe **solar wind** and the **Sun's Polar Regions.** ➤ **Significance:** Better understanding the solar cycle and magnetic field.
Chandrayaan -5/ LUPEX (Lunar Polar EXploration) Mission	ISRO & JAXA (Japan)	➤ **Objective:** To study **lunar volatile materials,** of the **South Pole.** ➤ **ISRO** will primarily build the **lander,** while **JAXA (Japan)** will provide the **rover.**
Orbiting Carbon Observatory (OCO)	NASA	➤ **Objective:** Global measurements of atmospheric carbon dioxide.
ESCAPADE (Escape and Plasma Acceleration and Dynamics Explorers) Mission	NASA	➤ **Objective:** To investigate how the solar wind interacts with Mars' magnetic environment and how this interaction drives the planet's atmospheric escape.

4.10. CRYOGENIC ENGINE

ISRO conducted the Boot-strap mode start test on CE20 Cryogenic Engine under vacuum conditions.

More on the News

- **CE20** is India's largest cryogenic engine developed by **Liquid Propulsion Systems Centre**, Valiamala, Kerala.
- **CE20 Cryogenic Engine** powering the LVM3 upper stage, has been qualified for Gaganyaan missions.

Cryogenic Engine

- A Cryogenic engine uses both cryogenic fuel and oxidizer, liquefied at a very low temperature.
- Used in the last stage (or upper stage) of a rocket.

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- **The working principle**: The thrust is produced by an internal combustion/pressure difference.
  - This follows Newton's Third law of motion- "Every action has an equal and an opposite reaction".
- On the other hand, semi-cryogenic engines **combine the benefits of cryogenic** and **conventional engines,** employing a **cryogenic oxidizer** (e.g., Liquid Oxygen), along with a **hydrocarbon-based fuel** (e.g., kerosene).

Advantages of Cryogenic Engine

- **Efficiency and Thrust:** Cryogenic propulsion offers superior thrust
- **Fuel Efficiency:** ISRO's PSLV Vikas engine burns 3.4 kg/sec, while cryogenic engines need only 2 kg/sec for the same thrust.
- **Eco-Friendly Technology:** Hydrogen-oxygen combustion emits only steam.
- **Heavy Payloads & Space Missions:** High efficiency makes cryogenic fuel ideal for heavy payloads and long missions.

4.11. NAVIC (NAVIGATION WITH INDIAN CONSTELLATION)

Why in the News?

During Operation Sindoor, India used **NavIC (Navigation with Indian Constellation)** across several layers of combat operations such as Missile guidance, Drone navigation, Battle Damage Assessment, etc.

About NavIC

Satellite Navigation Systems

- United States – GPS
- Russia – GLONASS
- European Union – Galileo
- China – BeiDou
- Japan-Quasi-Zenith Satellite System (QZSS)

- Developed by **ISRO**
  - It was erstwhile officially known as **Indian Regional Navigation Satellite System (IRNSS)**.
- **Coverage:** Provides accurate **Position, Velocity and Timing (PVT) service** up to region extending about **1500 km beyond** the **Indian landmass**.
- **Satellite Constellation:** Consists of **7 satellites** and a **network of ground stations** operating 24 x 7.
  - **3 satellites** are placed in **geostationary orbit** and **4** in inclined **geosynchronous orbit.**
  - These satellites are equipped with **dual-band signals (L5 and S-band)**.
    - The **L5 signal** is encrypted for **military use.**
- **Key services: Standard Position Service (SPS)** for civilian users and **Restricted Service (RS)** for strategic users.
- **Strategic advantages**
  - **Independence from GPS:** India could strike deep without relying on any **foreign-owned navigation signals.**
  - **Encrypted Military Channel:** Prevents jamming or spoofing during missile and drone missions.
  - **Faster Signal Lock:** Provides higher accuracy over the **Indian subcontinent than even GPS in some regions**.

4.12. HOPE ANALOG MISSION

Why in the News?

ISRO inaugurated **Himalayan Outpost for Planetary Exploration** (HOPE) Analog Mission in Tso Kar Valley, Ladakh.

About HOPE Mission

- A specially designed **Habitat Module** for crew living and a **Utility Module** for operations and support systems which are interconnected for seamless workflow.

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- **Led by: ISRO's Human Space Flight Centre (HSFC)**, with industry partners and top Indian institutions.
- **Objectives**
  - Simulates extraterrestrial environments like the Moon and Mars.
  - Enables testing of human survival, health protocols, and equipment in space-like environments.
- **Studies to be conducted:** Epigenetics, genomics, physiology, psychology, Sample collection and microbial analysis techniques, etc.
- Aimed at preparing for long-term extra-terrestrial human missions.
- **Other similar research stations across the World:** Mars Desert Research Station of the US, Flashline Mars Arctic Station of Canada, and BIOS-3 of Russia.

Why Tso Kar Valley was chosen?

- **Mars-like conditions**: **High UV radiation**, **Low atmospheric pressure**, **Extreme cold** and **Saline permafrost**
- Supports both **technological tests** and **astrobiology research**.

4.13. LUNAR MODULE LAUNCH VEHICLE (LMLV)

Why in the News?

ISRO's heaviest rocket Lunar Module Launch Vehicle (LMLV) will be ready by 2035.

Key Features of LMLV

- **Design**: **Improved version** of the **NGLV (Next Generation Launch Vehicle)**.
- **Purpose**: **Lunar missions**, including India's first human mission to the Moon, planned by 2040.
- **Three Stages Involved:** 3 Stages: Liquid propellant for its first two stages and a cryogenic propellant for its third stage.

ISRO's Key Launch Vehicles and Capabilities

- **PSLV (Polar Satellite Launch Vehicle):** ISRO's **workhorse** (due to its consistent performance), a third-generation vehicle, capable of launching satellites into **Sun-synchronous Polar Orbit, LEO, GTO** (e.g., Chandrayaan-1, Mars Orbiter Mission).
  - It is a **four-stage vehicle** and **first Indian launch vehicle** to be equipped with **liquid stages.**
- **GSLV (Geosynchronous Satellite Launch Vehicle):** A fourth-generation, three-stage vehicle designed to launch **2.0-ton class satellites into GTO** for communication satellites.
- **LVM 3**: A heavy-lift, three-stage vehicle capable of carrying **4-ton class satellites to GTO or about 10 tons to LEO**.
  - It is proposed to be used for **Bharatiya Antariksh Station**.
    - Recently, Godrej Enterprises delivered the first human-rated L110 stage Vikas engine for Gaganyaan project to ISRO.
- **SSLV (Small Satellite Launch Vehicle):** Three-stage, all-solid propulsion vehicle designed for launching **Mini, Micro, or Nano satellites**.

Related News

PSLV-C61/EOS-09 Mission

- ISRO's 63rd PSLV mission (PSLV-C61/EOS-09) failed due to a **technical malfunction during the third stage** of the **PSLV rocket.**
  - Since its first flight, PSLV has **failed only twice**.
- **About PSLV-C61/EOS-09 Mission**
  - **EOS-09** is an **advanced Earth observation satellite**, equipped with **C-band SAR** technology.
  - **Objective:** To provide **continuous and reliable remote sensing data** for operational applications across various sectors.

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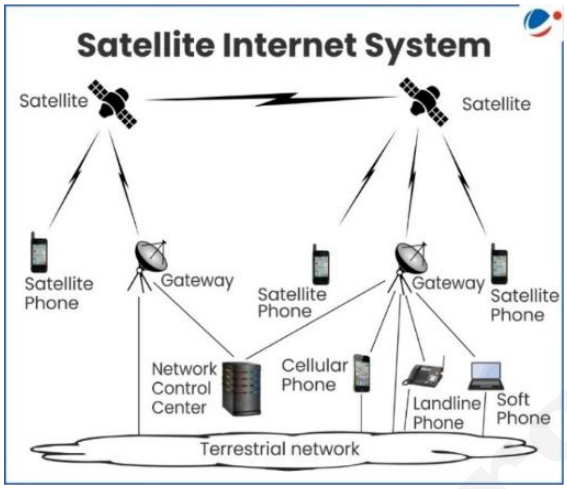
4.14. SATELLITE INTERNET SERVICES

Why in the News?

Elon Musk-owned Starlink has signed an agreement with Maharashtra government to deliver satellite-based connectivity to remote and underserved regions.



About Satellite Internet (or satellite broadband)

- A **wireless internet connection** provided through communication satellites **orbiting the Earth.**
- Unlike **land-based internet services** such as fiber, cable, or DSL, it **doesn't rely on wires to transmit data.**
- **Infrastructure:** Generally includes three segments:
  - **Space Segment:** It is mainly a constellation system **composed of several communication satellites**.
  - **Ground segment:** Includes satellite measurement and **control networks, gateway stations,** etc.
- **Latency:** Satellite internet typically has **higher latency compared to traditional wired connections** due to the distance data must travel to and from the satellite.

Various prominent Satellite Internet projects in the world

- **Project Kuiper**: by **Amazon**
- **Starlink:** Launched by **SpaceX**
- **OneWeb:** By French satellite operator Eutelsat, and currently operates the world's second-largest satellite constellation fleet after SpaceX
- **Qianfan constellation:** Planned **Chinese low-Earth orbit satellite internet megaconstellation**.

4.15. SPACE RELATED PHENOMENON

4.15.1. SOLAR FLARES

Why in the News?

NASA's satellites recently detected a **massive solar flare**, with superheated plasma erupting from the Sun and spreading out in dramatic "wing-like" shapes.

More on the News

- Recently, **Chandrayaan-2 Lunar Orbiter** (**Chandra's Atmospheric Composition Explorer-2 (CHACE-2)**) has made first-ever observation of effects of sun's **Coronal Mass Ejection (CME)** on moon.

What are Solar Flares?

- **Definition:** Solar flares are **giant explosions** on the sun that send energy, light and high speed particles into space.
  - They are often associated with **solar magnetic storms** known as **coronal mass ejections** (CMEs).
- **Classification:** The biggest flares are known as **"X-class flares"**. The smallest ones are **A-class** (near background levels), followed by B, C, M and X.
- **Frequency:** Flares occur more frequently during the **solar maximum** (peak of the **11-year solar cycle)**.
  - During the solar cycle, the **Sun's magnetic poles flip**, reversing polarity approximately every 11 years.
- Solar flares bursts emit radiation across the **electromagnetic spectrum**, including **X-rays, gamma rays, ultraviolet light, visible light, radio waves**, etc.

Coronal Mass Ejections (CMEs)

- They are large **expulsions of plasma** and **magnetic field** from the Sun's corona.
- They can eject billions of **tons of coronal material** and carry an **embedded magnetic field.**

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- The fastest Earth-directed CMEs **can reach our planet in as little as 15-18 hours.** Slower **CMEs can take several days to arrive.**

Implications of Solar Flare Events

- **Geomagnetic Storms:** These flares can disturb Earth's magnetic field, leading to **radio blackouts, power grid failures,** & stunning **auroras.**
- **Satellite Damage:** High-energy particles can **damage satellite electronics,** affect **GPS** systems, & degrade **communication networks.**
- **Human Safety: Do not directly harm** people on Earth because the **magnetic field** & **atmosphere** shield us.
  - However, astronauts & space missions can be **at risk** due to radiation exposure.

The Sun's Activity Cycle

- The Sun goes through cycles of activity, **with periods of high and low activity**.
- **These cycles last about 11 years**, and during the peak of the cycle, called the **solar maximum**, there are frequent **solar storms** and increased instances of **sunspots** (cooler regions on the Sun's surface)
  - This is because the **Sun's magnetic fields are** more complex and twisted during this phase, leading to more eruptions and ejections of charged particles.

4.15.2. SPACE DEBRIS

Why in the News?

Starlink has **lost 523 satellites from 2020 to 2024**, the years associated with the **peak of Solar Cycle.** It raised concerns about atmospheric pollution and space Debris

Space Debris and its Status

- Includes **all non-functional, man-made objects, including fragments and elements thereof**, in Earth orbit or **re-entering into Earth's atmosphere.**
- **Key Sources:** Majority of debris objects originate from **on-orbit break-ups as well as on-orbit collisions.**
- **Potential Consequences:** It can damage satellites, disrupt communication and navigation systems, and potentially endanger astronauts.
  - Additionally**, space debris** can contribute to **Kessler Syndrome,** a theoretical scenario where **collisions generate more debris,** making **certain orbits unusable.**

Initiatives taken to tackle Space Debris

- **Global**
  - **Inter-Agency Debris Coordination Committee (IADC),** established in 1993
  - **Zero Debris Charter:** Signed by 12 countries - Austria, Belgium, Cyprus, etc.
- **India**
  - **Debris Free Space Missions (DFSM) 2030.**
  - **ISRO System for Safe and Sustainable Operations Management (IS4OM)**
  - **Project Network for Space Object Tracking and Analysis (NETRA)**

4.16. KEY CONCEPTS/TERMS IN NEWS

4.16.1. BROWN DWARFS

Scientists discover a rare quadruple star system – **UPM J1040–3551 AabBab** – in the Milky Way.

- It consists of a **pair of cold brown dwarfs orbiting a pair of young red dwarf stars**.

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About Brown Dwarfs

- Brown dwarfs are celestial bodies that **form like stars** (from collapsing gas and dust) but **lack enough mass for sustained hydrogen fusion** (a process that heats the star).
  - Thus, they are often known as **failed stars**.
- They have **atmospheres similar to gas giant planets such as Jupiter**.
  - The major difference between brown dwarfs and planets is their **mass and occurrence of deuterium** (heavy hydrogen) in brown dwarfs.

4.16.2. SUPER EARTH

Astronomers using **data from NASA's Transiting Exoplanet Survey Satellite (TESS)** have found a **new super-Earth** named **TOI-1846.**

About Super Earth

- Super-Earths are a type of **exoplanet (**planets outside our solar system). The name refers only to their **size and mass**, not to Earth-like features.
- **Size & Mass**: They are **larger than Earth** (up to **twice its size**) and **more massive** (up to **10 times Earth's mass**), but **lighter than Neptune**.
- **Uncertain Nature**: These planets are **unlike any in our solar system**, and their true composition is still unclear.
- The larger ones are sometimes called **sub-Neptunes** or **mini-Neptunes**.

4.16.3. EXTREME NUCLEAR TRANSIENTS (ENTS)

Astronomers identified a new category of events: Extreme Nuclear Transients (ENTs).

About ENTs

- ENTs occur when **stars with masses at least three times** greater than that of the sun are torn apart by supermassive black holes.
- As a **star nears a black hole's event horizon,** extreme tidal forces stretch and compress the star into a long, thin spaghetti-like shape, releasing enormous amounts of electromagnetic energy. This emission is the ENT.

4.17. OTHER IMPORTANT NEWS

4.17.1. JAMES WEBB SPACE TELESCOPE (JWST)

Cambridge Scientists discovered Biosignatures on Exoplanet **K2-18 b**, using James Webb Space Telescope (JWST).

About JWST

- Launched jointly by NASA, ESA and Canadian Space Agency
- **Type:** Orbiting infrared observatory.
- **Orbit:** Orbits the Sun 1.5 million kilometers away from the Earth at second Lagrange point or L2.
- **Purpose:** Study every phase in the history of our Universe, ranging from the first luminous glows after the Big Bang, to the formation of solar systems.

4.17.2. SUNBIRD

Sunbird, a **nuclear fusion powered rocket** could help reach **Pluto** in just 4 years as per reports.

About Sunbird

- A **nuclear fusion-based rocket** being developed by Pulsar Fusion (UK) and Princeton Satellite Systems (USA).
- Powered by **Dual Direct Fusion Drive (DDFD) technology**.
  - Using **helium-3** and **deuterium**, DDFD generates both thrust and electricity, marking a revolutionary step in interplanetary travel.

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4.17.3. 3I/ATLAS

NASA funded **ATLAS (Asteroid Terrestrial-impact Last Alert System)** survey telescope in Chile discovered an **interstellar Comet** named 3I/ATLAS.

About 3I/ATLAS

- 3I/ATLAS is an **active comet.**
- It is categorized as interstellar because of the **hyperbolic shape** of its orbital path.
  - **It does not follow** a closed orbital path about the Sun.

4.17.4. KODAIKANAL SOLAR OBSERVATORY

Researchers from the **Aryabhatta Research Institute of Observational Sciences (ARIES)** tapped the century old data from the **Kodaikanal Solar Observatory** to reconstruct the Sun's past polar magnetic behaviour.

About Kodaikanal Solar Observatory (1899)

- **Operated by: Indian Institute of Astrophysics**, an autonomous institute of DST.
- **Location:** Palani Range of hills in Southern India
- Known for the discovery of **Evershed Effect.**
  - It is **nearly horizontal outflow** of gases observed in the **penumbrae** of sunspots in the **photospheric layer** (visible surface of the Sun).

4.17.5. VIKRAM-1

Prime Minister unveiled Vikram-1, which is India's new private orbital-class launch vehicle.

About Vikram-1

- **Developer:** Skyroot Aerospace — a private Indian space-startup based in Hyderabad.
- **Purpose:** To launch satellites into LEO or SSO; designed to serve small satellites and rideshare missions.
- **Propulsion:** Four-stage rocket — the first three stages use solid-fuel boosters, the final (upper) stage uses a liquid-propellant "Raman" engine for precise orbital insertion.
- **Structure:** The rocket uses an all-carbon-fibre body and features 3D-printed engines, aiming for lightweight, efficient design.

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5. HEALTH

5.1. DISEASES AND RELATED DEVELOPMENTS

5.1.1. TUBERCULOSIS (TB)

Why in the News?

According to the WHO Global TB Report 2025, **India's TB incidence (new cases emerging each year) reduced by 21%.**

About Tuberculosis (TB)

- A contagious airborne disease caused by a bacterium called **Mycobacterium tuberculosis**.
- **Types based on site of Infection:**
  - **Pulmonary TB**: Most common form affecting the **lungs**, and is contagious spreading through airborne droplets through coughing or sneezing.
  - **Extrapulmonary TB**: Occurs **outside the lungs**, affecting organs like lymph nodes, bones, brain, kidneys, or the pleura, less contagious and spreads within the body from lungs.
  - **Spinal TB (Pott's disease):** Affects the spine and can cause severe back pain and mobility issues.
- **Types based on Response to Drugs**:
  - **Drug-sensitive TB**: This form of TB responds well to the standard first-line anti-TB medicines such as isoniazid and rifampicin.
  - **Drug-Resistant TB**: Some forms of TB do not respond to standard medicines.
    - **Multi Drug Resistant (MDR-TB)**: Form of TB that does not respond to rifampicin and isoniazid, the two most effective first-line TB drugs.
    - **Extensively Drug-Resistant (XDR-TB)**: In this type of TB, the stronger medicines may not work.

5.1.2. HUMAN IMMUNODEFICIENCY VIRUS (HIV)

Why in the News?

US Food and Drug Administration (FDA) approves new Human Immunodeficiency Virus (HIV) prevention drug **Lenacapavir**.

About Lenacapavir

- Lenacapavir is an antiretroviral medicine that is used for **HIV prevention** as a **Pre-Exposure Prophylaxis or PrEP.**
  - PrEP is a medication that **can reduce the risk of HIV infection for individuals** who are **HIV-negative but are at risk of contracting the virus.**

About HIV

- A **virus that attacks the body's immune system.**
- **Mechanism:** HIV damages the immune system by infecting and destroying **CD4 cells (CD4 T lymphocytes),** a type of **white blood cells.**
- **Transmission: Body fluids** of an infected person, including blood, breast milk, semen and vaginal fluids.
  - It can also **spread from a mother to her baby**.
- **Treatment:** HIV can be prevented and treated with **antiretroviral therapy (ART)**.
  - Untreated HIV can progress to **acquired immunodeficiency syndrome (AIDS).**

5.1.3. OTHER DISEASES IN NEWS

5.1.3.1. TRACHOMA

India was awarded the Certificate of **Elimination of Trachoma** as a **Public Health Problem** by the **WHO.**

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- India was declared the **3rd (after Nepal and Myanmar)** Southeast Asian region country to have eliminated Trachoma.

About Trachoma

- An eye disease caused by the **bacterium Chlamydia trachomatis.**
  - It is categorized as a **Neglected Tropical Disease** by the WHO.
- **Impact:** Irreversible blindness
- **Spread:** Personal contact or through flies
- **Indian Initiative:** Trachoma control program integrated under the **National Program for Control of Blindness and Visual Impairment (NPCBVI)**

5.1.3.2. HEPATITIS

WHO has classified Hepatitis D as Cancer-Causing, like Hepatitis B and C.

- **Hepatitis D** is an **incompetent virus** that requires **hepatitis B virus (HBV)** for replication.
- This means hepatitis D **only affects people who already have hepatitis B** either simultaneously or sequentially.

About Hepatitis Virus

- Viral hepatitis (**types A, B, C, D, and E)** are major **causes of acute liver infection.**
- However, **only hepatitis B, C, and D can lead to chronic infections with a higher risk of liver cirrhosis,** failure or cancer.
- **Vaccine Availability**
  - There is **no vaccine** for **Hepatitis C virus.**
  - **Hepatitis B vaccines** provide **protection from HDV infection.**
  - **Havisure** is India's first indigenous Hepatitis A vaccine.

5.1.3.3. MPOX (MONKEYPOX)

WHO chief says mpox outbreak in Africa is no longer a global health emergency.

About Mpox

- **Type:** Viral zoonotic disease caused by **Monkeypox virus (Orthopoxvirus genus).**
- **Transmission:** Close contact with infected **people, animals, or contaminated objects.**
- **Symptoms:** Fever, headache, muscle aches, fatigue, swollen lymph nodes.
- **Global Concern**: Declared a **Public Health Emergency of International Concern (PHEIC)** by WHO.
- There is no **proven treatment** for Mpox.
- **Diagnostic Test:** RT-PCR (Reverse Transcription Polymerase Chain Reaction)

5.1.3.4. HUMAN PAPILLOMAVIRUS (HPV)

India's first indigenously developed **HPV test kits** for cervical cancer screening validated by **DBT.**

About HPV

- A **common sexually transmitted infection** which can affect the skin, genital area and throat.
- In **most** cases the immune system clears HPV from the body.
- **Persistent infection with high-risk HPV** can cause abnormal cells to develop, which go on to become cancer.
  - **Cervical cancer** is the most common type of cancer caused by HPV.
- **Treatment:** There is currently no treatment for HPV infection.

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5.2. NOBEL PRIZE IN PHYSIOLOGY OR MEDICINE 2025

Why in the News?

Mary E. Brunkow, Fred Ramsdell and Shimon Sakaguchi have been awarded Nobel Prize in Physiology or Medicine 2025 for their discoveries concerning **peripheral immune tolerance**.

More on the News

- Our **immune system** protects the body from harmful pathogens like viruses, bacteria, and fungi.
- However, it must also make sure **not to attack its own cells** — this balance is very important for healthy body function.
- The immune system uses **two types of tolerance** to achieve this — **central tolerance** and **peripheral tolerance**.

Central Tolerance

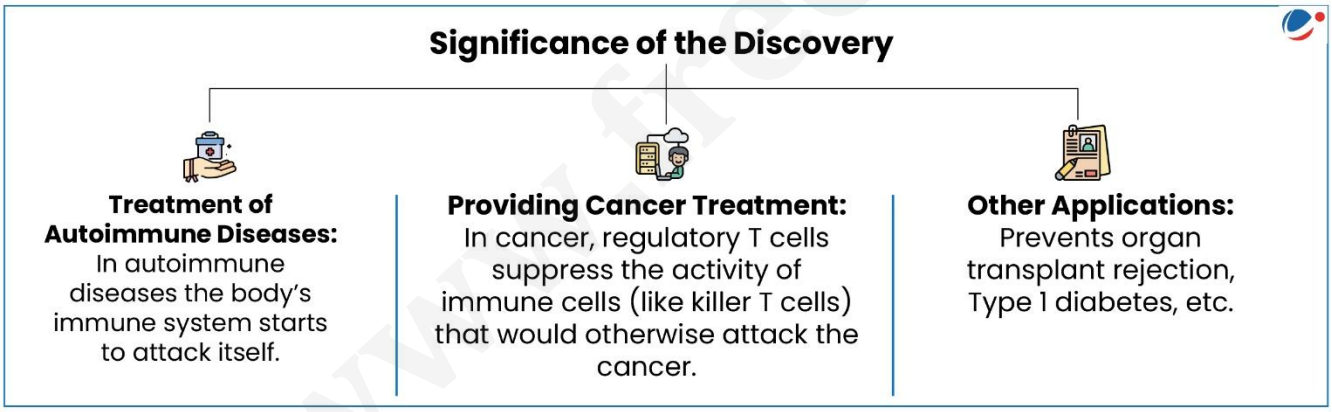
- This process happens in the **thymus**, a small gland in the lymphatic system that produces and trains T cells (a type of white blood cell).
  - **T cells** protect our body from infections.
- During training, the thymus removes **self-reactive T cells** (harmful cells).
- Some of these self-reactive T cells **escape from the thymus** and enter the body's circulation and tissues, known as the **periphery**.

Peripheral Tolerance

- **Additional control** is needed to prevent escaped self-reactive T cells from attacking the body.
  - Here, **Regulatory T cells (Treg cells)** play a key role.
- Regulatory T cells **identify self-reactive T cells** and **stop them** from attacking our own tissues.
- In this way, Treg cells act as a **security guard**.

Role of the FOXP3 Gene

- **Mary Brunkow** and **Fred Ramsdell** discovered the **FOXP3 gene**, which **controls the development and function** of regulatory T cells.
  - If there is a **mutation in the FOXP3 gene**, regulatory T cells do not form properly.
- This can cause a **rare autoimmune disease called IPEX**, where the immune system attacks the body's own tissues.



5.3. ANTIMICROBIAL RESISTANCE (AMR)

Why in the News?

The **World Health Organization (WHO)** released the **Global Antibiotic Resistance Surveillance Report 2025**.

What is meant by Antimicrobial Resistance (AMR)?

- AMR occurs when **bacteria**, **viruses**, **fungi,** and **parasites** evolve to **withstand** the **drugs designed** to **kill them**.

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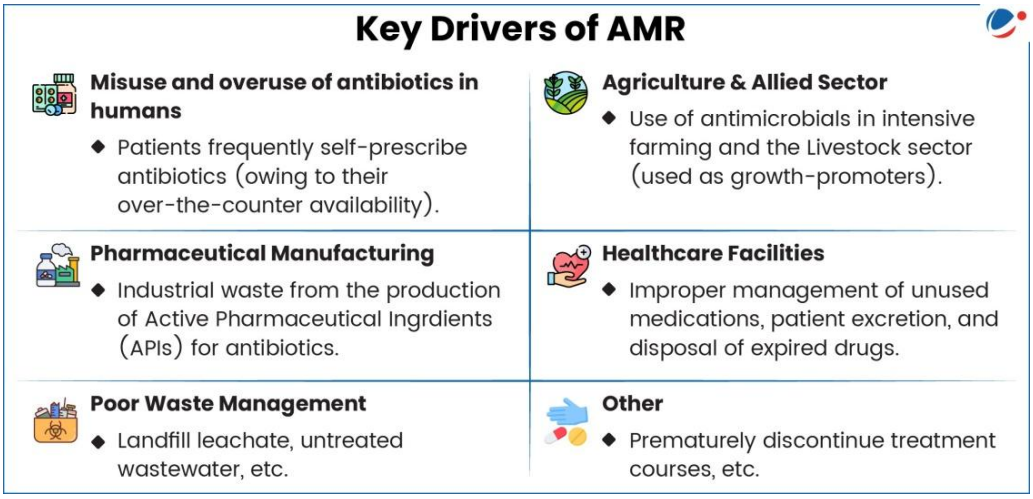
- AMR is a **natural process** that happens over time through **genetic changes** in **pathogens**.
  - However, its emergence and spread are accelerated due to several anthropogenic factors.
- Strains of bacteria, viruses, parasites, and fungi that are resistant to most **antimicrobials** are called **Superbugs.**
- Spread through **vertical gene transfer** during bacterial division and through **horizontal gene transfer** by exchange of resistance genes among microbes.
- WHO recognized AMR as one of the **top ten global health threats**.
  - It is often described as a **silent pandemic**.



5.4. FIXED-DOSE COMBINATION (FDC) DRUGS

Why in the News?

Central Drugs Standard Control Organisation (CDSCO) has directed all states and Union Territories to stop the manufacture, sale, and distribution of 35 unapproved FDC drugs.

About Fixed-Dose Combination (FDC) Drugs

- FDC refer to products **containing one** or **more active ingredients** used for a **particular indication(s)**.
  - **Active Ingredient** is the **biologically active component** of a drug product (tablet, capsule, cream, injectable) that produces the intended effects.
- **FDCs** are considered **new drug** (under **NDCT) Rules, 2019**) when it meets two conditions:
  - It combines two or more drugs already approved for individual use in a fixed ratio.
  - It alters the ratio of drugs in an already approved FDC, along with making changes to its claims.

Why FDC drugs are Preferred?

- **Better Therapeutic Outcomes:** Enhanced synergistic effects between combined drugs (when rationally selected).
- **Improved Patient Compliance:** Reduces the **pill burden**.
- **Reduced Cost of Therapy:** Combined products may lower costs compared to purchasing multiple individual drugs.

Regulation of Pharma Products in India

- **Drugs and Cosmetics Act, 1940 & Drugs and Cosmetics Rules, 1945:** Governs import, manufacture, distribution, and sale of drugs and cosmetics in India.
- **Central Drugs Standard Control Organisation (CDSCO):** Under Directorate General of Health Services, Ministry of Health & Family Welfare is **National Regulatory Authority of India**.
  - Under **Drugs and Cosmetics Act**, CDSCO is responsible for approval of Drugs, Conduct of Clinical Trials, laying down the standards for Drugs, control over the quality of imported Drugs in country.
- **State Drug Regulatory Authorities:** Empowered to grant licenses, conduct inspections, and ensure compliance with drug laws at state level.
- **National Pharmaceutical Pricing Authority (NPPA):** Enforces provisions of Drugs (Prices Control) Order.
- **Good Manufacturing Practices (GMP):** Schedule M of Drugs and Cosmetics Rules prescribes Good Manufacturing Practices (GMP), which align with WHO guidelines.

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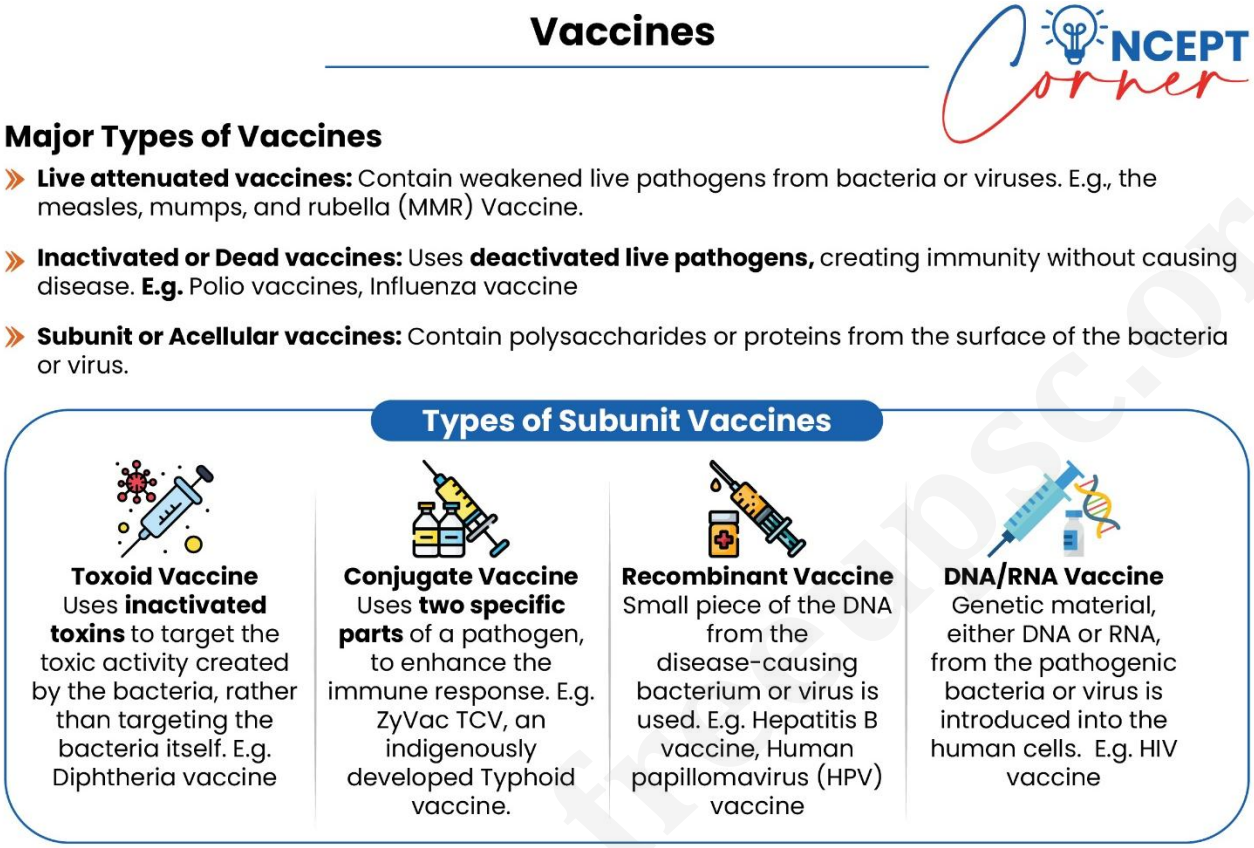
Related News

SHRESTH Initiative

- Union Health Ministry launched **State Health Regulatory Excellence Index (SHRESTH)**, a national initiative to benchmark and strengthens state drug regulatory systems.
- **About SHRESTH**
  - Proposed by the CDSCO.
  - **Aim:** To drive improvements in the performance of state drug regulatory authorities across India, ensuring drug safety and quality standards are consistently met.

5.5. VACCINE IN NEWS



5.5.1. ADFALCIVAX VACCINE

Why in the News?

Government of India has licensed private firms to produce its **first indigenous multi-stage malaria vaccine**, AdFalciVax.

More on the News

- Vaccine is being developed through **ICMR's Regional Medical Research Centre, Bhubaneswar** and **National Institute of Malaria Research** in partnership with **Department of Biotechnology-National Institute of Immunology.**

About AdFalciVax Vaccine

- **Dual-Stage Targeting of Plasmodium falciparum (Deadliest malaria parasite Species):** Unlike existing vaccines (**RTS, S/AS01 (Mosquirix)** and **R21/Matrix-M**) that target only one life stage; it targets two critical stages in parasite's lifecycle i.e. **Pre-erythrocytic (liver) stage** and **Transmission (sexual) stage**.

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- **Recombinant Chimeric Vaccine:** A **chimeric vaccine** refers to vaccine that c**ombines antigens from different stages of a parasite's life cycle** into a single immunogen.

About Malaria

- **Life-threatening disease** caused by Plasmodium parasites.
  - **Malaria** mostly spreads to people through bites of some **infected female Anopheles mosquitoes.**
- **Five Plasmodium species cause malaria in humans:** P. falciparum, P. vivax, P. malariae, P. ovale, P. knowlesi.

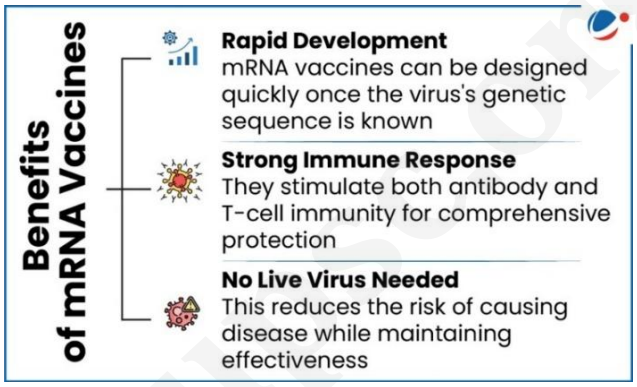
5.5.2. ONCOLYTIC & PERSONALIZED MRNA VACCINES

Why in the News?

Russia is developing oncolytic vaccine Enteromix and Personalized **messenger RNA** (mRNA) cancer vaccines for cancer treatment.

About Oncolytic Vaccine Enteromix

- An Oncolytic vaccine uses **oncolytic viruses (OVs)** to directly **kill cancer cells and stimulate an anti-tumor immune response.**
  - Enteromix is based on a **combination of four non-pathogenic viruses** that have the ability to destroy malignant cells and simultaneously **activate the patient's antitumor immunity.**



About Personalized mRNA Vaccines

- **Personalized Vaccine:** Based on the genetic analysis of each patient's cancer cells.
- **mRNA vaccines**: The vaccine contains a **synthetic mRNA strand** that **encodes** a **specific protein** from the virus
  - mRNA **delivers genetic material,** encapsulated in **lipid nanoparticles**, into body to prompt protein production that match up with parts of pathogen called **antigens.**
  - **E.g.,** the mRNA vaccine for COVID-19 directed cells to produce copies of a protein on the outside of the coronavirus known as the spike protein.

Related News

Self-amplifying mRNA (saRNA) Vaccine

- Gennova Biopharmaceuticals is developing a **pioneering self-amplifying mRNA (saRNA)** vaccine candidate against the **Nipah virus,** as part of expanded funding from the **Coalition for Epidemic Preparedness Innovations (CEPI)**.
- **saRNA vaccines work by giving the body instructions to replicate mRNA** needed to create the desired antigen, potentially **enhancing the immune response with lower doses** compared to existing mRNA vaccines.

5.6. OTHER IMPORTANT NEWS/DEVELOPMENTS

5.6.1. WHO PANDEMIC AGREEMENT

WHO member states held their first meeting of the **Intergovernmental Working Group (IGWG)** on the WHO Pandemic Agreement.

About WHO Pandemic Agreement

- **Second international legal agreement** negotiated under **Article 19** of the **WHO Constitution** (first being the **WHO Framework Convention on Tobacco Control, 2003**).

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- **Key Highlights of the Agreement**
  - **Strengthen Pandemic prevention and surveillance**: As per **International Health Regulations (IHR), 2005.**
  - **Pathogen Access and Benefit Sharing system (PABS):** A **process** to draft and negotiate PABS through an **Intergovernmental Working Group (IGWG)** was launched.

5.6.2. UNIVERSAL IMMUNIZATION PROGRAMME (UIP)

WHO/UNICEF 2024 estimates show significant progress on Immunization in India.

Universal Immunization Programme (UIP) of India

- **Coverage**: Provides free immunization against 12 diseases:
  - Diphtheria, Pertussis, Tetanus, Polio, Measles, Rubella, Childhood Tuberculosis, Hepatitis B , Meningitis & Pneumonia, Rotavirus diarrhoea, Pneumococcal Pneumonia, and Japanese Encephalitis.
- Under the **National Rural Health Mission**, the UIP has become a central component of India's public health efforts.
- **Achievements:** Polio-Free India and Neonatal tetanus elimination
- U-WIN Platform has been launched for the digitalization of all vaccination services provided under UIP.

5.6.3. MONOCLONAL ANTIBODIES (MABS)

The Indian Council of Medical Research **(ICMR)** seeks partners to develop monoclonal antibodies (mAbs) against Nipah viral disease.

- **Nipah virus** is a zoonotic pathogen causing severe respiratory and neurological illness, transmitted from bats or infected animals to humans.

About Monoclonal Antibodies (mAbs)

- **Definition**: Monoclonal antibodies are laboratory-produced proteins, engineered to bind specific antigens, mimicking natural immune responses.
- **Origin**: Derived from identical immune cells cloned from a single parent B-cell.
- **Function**: Used to diagnose, prevent, and treat diseases including cancers, autoimmune disorders, and viral infections.

5.6.4. 3 BY 35 INITIATIVES

WHO launched **3 By 35 Initiatives**, aims to raise prices of any or all of **three unhealthy products** tobacco, alcohol, and sugary drinks by **at least 50%** through **health taxes by 2035.**

What is Health Tax?

- **Levied on products** that have a **negative public health impac**t e.g. Tobacco, etc.
- WHO recommends taxation as one of the most **cost-effective tools for addressing population levels of obesity** and other related non-communicable diseases (NCDs).

5.6.5. NATIONAL ONE HEALTH MISSION

Union Government will launch **National One Health Mission (NOHM)**.

- **One Health** is an integrated, unifying approach to balance and optimize the health of people, animals and the environment.

About National One Health Mission

- **A multi-sectorial initiative** integrating **human, livestock, wildlife** and **environmental** health to strengthen coordinated surveillance, diagnostics and outbreak response.
- **Nodal Agency:** Anchored by Indian Council of Medical Research (**ICMR)** under **Office of the Principal Scientific Adviser (PSA)**

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- **Anchor Institution:** National Institute of One Health, Nagpur.
- **Need of the Mission:** Zoonotic Risk Mitigation, Pandemic Preparedness, curbing AMR, etc.

5.6.6. TRANSFATS

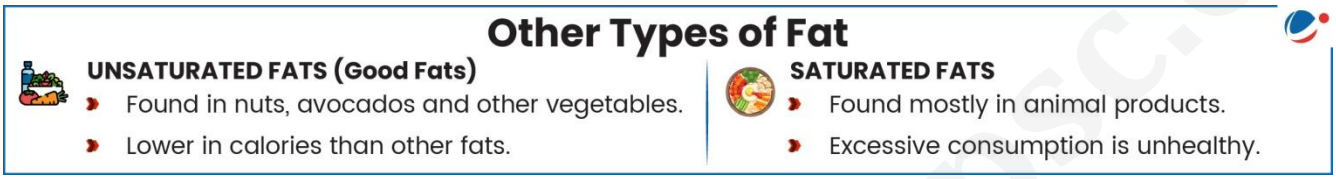
The WHO officially recognized four countries (Austria, Norway, Oman and Singapore) for their outstanding leadership in eliminating industrially produced trans fats.

About Trans fats (Trans-fatty acids (TFA))

- **Definition:** TFA are **unsaturated fatty acids** that can be **industrially produced** (via hydrogenation) or **naturally found** in **animal-source foods** (meat, milk).
  - Industrially produced trans fats are commonly found in baked goods like biscuits, margarine, and Vanaspati ghee, etc.
- **Health Impacts:**
  - **Raises the level** of the **bad cholesterol** and **low density lipoprotein-cholesterol** (LDL-c).
  - They have been also linked to **inflammation, overweight/obesity, high blood pressure, diabetes** and **some types of cancers.**

Key Initiative taken

- **WHO's "REPLACE" Action** Package
- **India enforced** limiting trans fats in oils to no more than 2 % through the **Food Safety and Standards (Prohibition and Restrictions on Sales) Second Amendment Regulations, 2021**.



5.6.7. WEIGHT LOSS DRUG

Danish pharma company Novo Nordisk launched its **weight loss drug Wegovy** in India**.**

- The drug **semaglutide**, marketed under the brand name Wegovy, will be available in the form of injections.
  - Semaglutide, works as an appetite suppressant by imitating a hormone called **glucagon-like peptide-1 (GLP-1).**
    - **GLP-1** is an intestinal hormone released after eating, and usually makes people feel fuller.
- Other weight loss drugs include Ozempic, **Mounjaro** (made up of **tirzepatide** (mimics function of GLP-1 and glucose-dependent insulinotropic polypeptide (GIP)), etc.

5.6.8. ORAL REHYDRATION SALTS (ORS)

Food Safety and Standards Authority of India (FSSAI) has directed states and UTs to **remove** beverages and similar **products being marketed using the term ORS**.

About ORS

- **ORS term** is associated exclusively with WHO-recommended **Oral Rehydration Salts**, which are drug products.
- **Purpose:** It is a simple, **low-cost glucose electrolyte solution** used to **prevent and treat dehydration from acute diarrhoeal diseases**.
- **WHO recommended ORS salts composition:** Sodium chloride, glucose (anhydrous), potassium chloride, and trisodium citrate (dihydrate).
- **Functions:** Glucose enhances **sodium** and **water absorption**, sodium and potassium **replace essential electrolyte losses**, and citrate help**s correct dehydration-related acidosis.**
- Developed by Dilip Mahalanabis.

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5.6.9. TYPES OF DIABETES

Malnutrition-related diabetes has been officially recognized and named **"type 5 diabetes"** at International Diabetes Federation's (IDF) World Diabetes Congress.

- Also called **J-type diabetes**, is known to be associated with **under nutrition and low weight (body mass index (BMI)).**
  - **Diabetes** occurs either **when the pancreas does not produce enough insulin** or when the body **cannot effectively use** the insulin it produces.
- It is a type of diabetes linked to **chronic undernutrition,** especially during **childhood or adolescence.**

Other Types of Diabetes

- **Type 1:** Autoimmune destruction of insulin-producing beta cells that prevents your pancreas from making insulin.
- **Type 2:** Mainly caused by **obesity and over nutrition (**Body does not use insulin well)**.**
- **Gestational:** Occurs with high blood glucose during pregnancy and can cause complications for both mother and child.

5.6.10. STEP-AND-SHOOT SPOT-SCANNING PROTON ARC THERAPY (SPARC)

For the first time, SPArc has been used to treat an Adenoid Cystic Carcinoma (ACC), a relatively **rare form of cancer.**

About Step-and-Shoot Proton Arc (SPArc)

- A kind of advanced **radiation therapy technique** (kills cancer cells or slows their growth by damaging their DNA).
  - It works by **targeting tumours** with **protons** while sparing surrounding tissue.
- **Benefits:** Improves the quality of radiation dose planning for various cancers like head and neck, brain, etc.

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6. DEFENCE

6.1. AIR DEFENCE SYSTEM (ADS)

6.1.1. INDIA'S AIR DEFENCE SYSTEM (ADS)

Why in the News?

India's Air Defence System (ADS) successfully thwarted attacks on India's Western Border.

India's Air Defence System (ADS)

India's ADS consists of an **Integrated Counter UAS (Unmanned Aerial Systems) Grid**, where following **surface-to-air missile (SAM) systems** played a key role.-

- **S-400 Triumf (Acquired from Russia)**
  - Also called **Sudarshan Chakra** in India.
  - Equipped with a **command-and-control system, phased array radars** and **electronic warfare countermeasures.**
  - Offers complete **360-degree radar and missile coverage.**
  - Multi-missile compatibility **enables layered defence.**
- **Barak 8 (Jointly developed by India and Israel)**
  - **Medium** to **long-range (MR SAM or LR SAM)**
  - Capable of **simultaneously engaging multiple targets** in the air.
  - Both **maritime** and **land-based variants** of the system exist.
- **Akash Weapon System (Indigenously Built)**
  - Short Range **SAM**
  - Equipped with **built-in Electronic Counter-Counter Measures (ECCM)**.
  - Can simultaneously e**ngage Multiple Targets in Group Mode or Autonomous Mode.**
  - High **immunity against active and passive jamming.**

Related News

Akashteer

- It played a pivotal role in neutralising drone and missile threats during border skirmishes with Pakistan.
- **About Akashteer**
  - India's fully indigenous, **automated Air Defence Control** and Reporting System.
  - Designed to automate detection, tracking and engagement of enemy aircraft, drones and missiles.
  - Reflects a strategic shift from **passive defence** to **proactive retaliation**.
  - **Key Features**:
    - > Part of the **C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance) framework.**
    - > Vehicle-based system, which makes it mobile.
    - > AI-driven and fully automated **air defence solution**
  - **Developed by**: Bharat Electronics Limited (BEL).

6.1.2. INTEGRATED AIR DEFENCE WEAPON SYSTEM (IADWS)

Why in the News?

DRDO successfully conducted maiden flight-tests of **Integrated Air Defence Weapon System (IADWS)**.

About IADWS

- **IADWS** is expected to provide **multiple layers** of protection by **integrating surveillance**, threat identification, and air defense systems.
  - It will help in detecting and neutralizing threats such as long-range missiles, aircraft, and unmanned aerial vehicles.

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- **Command Centre:** Integrated operation is controlled by a **Centralized Command and Control Centre** developed by Defence Research & Development Laboratory (DRDL).

Components of IADWS

- **Indigenous Quick Reaction Surface to Air Missiles (QRSAM):** Developed by DRDO
  - A **short-range** SAM system designed to protect moving armoured columns from aerial attacks.
  - Configured on **mobile platform**.
- **Advanced Very Short-Range Air Defence System (VSHORADS) missiles:** Developed by Research Centre Imarat (RCI)
  - **Man Portable Air Defence System (MANPADS)** designed to neutralize low-altitude aerial threats at short ranges.
- **A high-power laser-based Directed Energy Weapon (DEW):** Developed by **Centre for High Energy Systems and Sciences**

Related News

Project Kusha or Program Long Range Surface to Air missile (PGLRSAM)

- An **indigenous** initiative led by **DRDO** to develop a **long-range air defence missile system.**
- **Consists of Two Phases:**
  - **Phase 1:** Includes **4 interceptors'** variants (under developments**: M1, M2, M3** and **Naval variant**)
  - **Phase 2:** Aims to develop an even longer range (exceeding 600 km) interceptor missile.

Anant Shastra Air Defence System

- **Indian Army** has awarded a contract to BEL for development and supply of 'Anant Shastra' air defense system.
- **About Anant Shastra**
  - An indigenous **Quick Reaction Surface-to-Air Missile (QRSAM) system.**
  - **Developed by:** DRDO in collaboration with BEL and Bharat Dynamics Limited (BDL).
  - **Capabilities:** Highly mobile and agile with a range **of around 30 km.**

6.1.3. OTHER AIR DEFENCE SYSTEM IN NEWS

Name of system	Country	Specifications
Iron Dome, David's Sling, Arrow-2, Arrow-3	Israel	Iron Dome (short range), David's Sling (short to medium and medium to long range, Arrow (long range).
The Terminal High Altitude Area Defence (THAAD)	U.S.A.	Intercepts ballistic missiles.
Golden Dome	U.S.A.	Expected deployment by 2029. Inspired by **Israel's Iron Dome,** but it will include both **surveillance satellites and interceptor satellites** to target enemy missiles.
PATRIOT Missile Air Defence System (PMADS)	U.S.A.	PATRIOT **(Phased Array Tracking Radar for Intercept on Target)** is a **mobile surface-to-air missile defence system.**
Barak Magen	Israel	**Barak Magen** (the **Hebrew name of Lightning Shield**) is an advanced naval air defense system.
HQ-9 system	China	Inspired by the Russian S-300.

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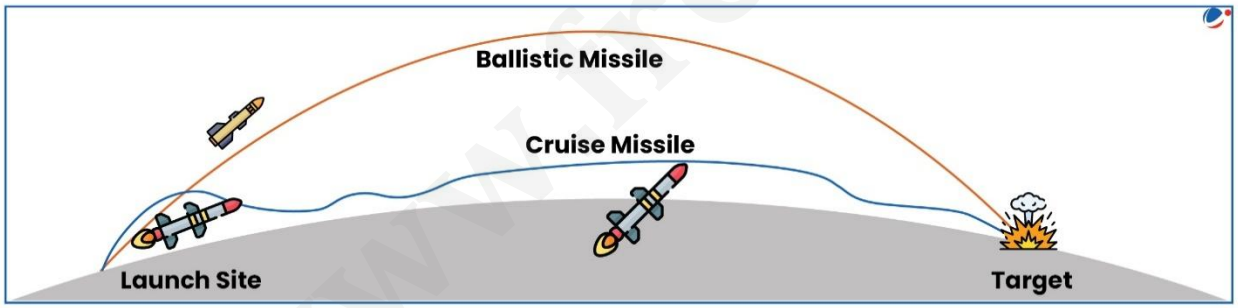
6.2. CRUISE AND BALLISTIC MISSILE

Cruise and Ballistic Missile

Comparison between Cruise and Ballistic Missile

Parameter	Cruise Missile	Ballistic Missile
About	Powered by jet engines for continuous flight throughout their journey. » **Types:** » **Subsonic cruise missile** (speed around 0.8 Mach) » **Supersonic cruise missile** (speed of around 2-3 Mach) » **Hypersonic cruise missile**	Rocket-powered for the initial boost phase, then coast unpowered for most of their flight » **Types:** Vary from **Short-range** (traveling less than 1,000 kilometers) to **Intercontinental ballistic missiles (ICBMs)** (traveling more than 5,500 kilometers)
Path	Flies at relatively **low altitudes** (within the earth's atmosphere)	Follows a **ballistic trajectory,** arcing upward into the atmosphere before descending to their target.
Range	Typically have **shorter ranges** but can loiter or change course more easily.	Generally, have longer ranges and higher top speeds.
Payload	Usually carry smaller, single warheads (conventional or nuclear).	Can carry larger payloads, including multiple warheads.
Interception	Harder to detect but easier to intercept after detection.	Easier to detect early but harder to intercept due to their speed
Example	BrahMos missiles	Prithvi and Agni Series of missiles



NOTE: Quasi ballistic missiles are a class of missiles that have low trajectory and take ballistic trajectory but can change course and make maneuvers during the flight if required.

6.2.1. AGNI-5 INTERMEDIATE-RANGE BALLISTIC MISSILE

Why in the News?

India successfully test-fired Agni-5 Intermediate-Range Ballistic Missile.

More on the News

- The launch was carried out under the **Strategic Forces Command (SFC)**.

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- SFC forms part of **India's Nuclear Command Authority** and is responsible for the management and administration of the country's **tactical and strategic nuclear weapons stockpile**.

About Agni-5

- A Nuclear-capable **Surface-to-Surface Ballistic Missile (SSBM)** and is powered by a **three-stage solid fuel engine**.
- **Range:** Over 5,000 km
- **Developed by**: DRDO
- Agni is **one of the five missile types** developed under the **Integrated Guided Missile Development Programme (IGMDP)**.
- **Significance:** Places India among few nations (US, Russia, China, France) with **Multiple Independently Targetable Reentry Vehicle (MIRV)**-capable ICBMs.

About IGMDP

- Started in 1983 to attain **self-sufficiency in the field of missile technology.**
- **The missiles developed under the program were**
  - **Prithvi**: Short-range surface-to-surface ballistic missile**.**
  - **Trishul**: Short-range low-level surface-to-air missile**.**
  - **Akash**: Medium-range surface-to-air missile**.**
  - **Nag**: Third-generation anti-tank missile**.**

Agni Prime

- DRDO & Strategic Force Command (SFC) successfully launched the **Agni-Prime Missile** from a **Rail based Mobile launcher system**.
  - This is first-of-its-kind **futuristic rail-based missile system** that can move on rail networks **without pre-conditions**.
- **About Agni-Prime Missile**
  - **Two-stage, solid-fueled, canister-launched ballistic missile**.
    - It can carry **both conventional and nuclear warheads**.
  - First of the new generation of missiles after the end of the IGMDP.

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6.2.2. OTHER MISSILES IN NEWS

Missile	Key Detail/Features

BrahMos Missile
	➤ **Jointly developed** by India and Russia.
	➤ **A long-range supersonic cruise missile** that can be launched from **land, sea and air.**
	➤ **Two-stage system:**
	  ➤ **1st stage (Solid propellant booster):** Gives the initial supersonic speed.
	  ➤ **2nd stage (Liquid ramjet):** Takes the missile closer to **3 Mach** speed in cruise phase.
	➤ **Range:** Up to 290 km.
	➤ **Special Capabilities:**
	  ➤ **Fire and Forget** technology.
	  ➤ Shorter flight times lead to lower target dispersion and quicker engagement.

 Astra Missile	➤ Indigenous **Beyond Visual Range Air-to-Air missile (BVRAAM).** ➤ Designed **to engage and destroy highly manoeuvring supersonic aircraft.** ➤ **Developed by:** DRDO ➤ The missile has **all weather day and night capability.** ➤ Equipped with state-of-the art **guidance and navigation systems.** ➤ **Range:** Exceeds 100 kms.
 Pralay missile	➤ A **surface-to-surface short range solid propellant quasi-ballistic missile .** ➤ Can fly at **hypersonic speed.** ➤ **Developed indigenously by:** Hyderabad-based DRDO facility RCI in collaboration with other facilities. ➤ **Strike Range:** From 150 to 500 km.
 Akash Prime	➤ **Developed by** DRDO. ➤ Hard and rugged version of the **indigenous Akash SAM system.** ➤ Designed to **operate in very extreme weather in cold areas, high altitude (above 4500 meter)** and **low-oxygen environments.**
 ULPGM-V3	➤ **ULPGM-V3 (UAV Launched Precision Guided Missile (ULPGM)-V3) is developed by** DRDO. ➤ Equipped with a **high definition dual-channel seeker** that can strike a wide variety of targets. ➤ **Significance:** Can be fired in plain and high-altitude areas. ➤ Day-and-night capability and two-way data link to support post-launch target/aim-point update.
 Rampage Missiles	➤ Long range, air to ground precise attack missile. ➤ Travel at **supersonic speeds,** making it difficult to detect. ➤ **Developed by:** Israel Aerospace Industries.

6.3. SCRAMJET ENGINE

Why in the News?

Defence Research & Development Laboratory (DRDL), a laboratory of DRDO, successfully **completes 1000+ seconds Active Cooled Scramjet Subscale Combustor** ground testing.

More on the News

- This marks crucial milestone in developing **Hypersonic Weapon Technology**.

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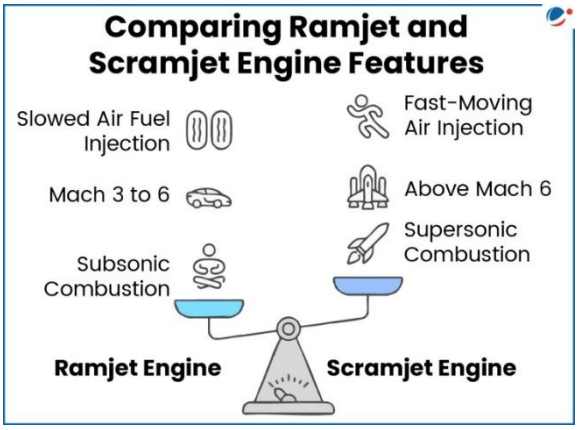
About Scramjet Engine



- A scramjet engine means a **Supersonic Combusting Ramjet engine**.
  - It is an improvement over the **ramjet engine**.
    - A **ramjet** is a form of **air-breathing jet engine** that uses the **vehicle's forward motion** to **compress incoming air** for combustion without a **rotating compressor**.
- **Key Features**:
  - **Uses flame stabilisation technique:** This holds **continuous flame** inside the combustor.
  - **Depends on assisted take off**: Both ramjets and scramjets **cannot produce thrust** at **zero air speed**.
    - Therefore, a **scramjet-powered vehicle** requires an **assisted take off** by a rocket to accelerate it to a speed where it begins to produce thrust.
- India is part of **elite club of nations** that have successfully tested scramjet engines which includes the **USA, Russia, China,** etc.

Advantages of Scramjet Technology

- **Increased Efficiency:** It is a more **efficient propulsion system** than a rocket.
  - A **rocket engine** carries both fuel and oxidizer, while a **jet engine** relies on **atmospheric oxygen** for combustion.
- **Enhanced Space Access:** It will reduce the cost of space missions as jet engines are re-usable.
  - Also, rockets fitted with **scramjet engines** will be able to carry heavier satellites.
  - An ISRO project named **AVATAR**, aimed at developing a rocket to launch the **ramjets** and **scramjets** engine.

Hypersonic Weapon

- Travel at **Mach-5 or faster,** or **at least five times the speed of sound** and is powered by **Air breathing engine.**
- Fly at **lower altitudes than ballistic missiles,** making them harder to track.
- **Types:**
  - **Hypersonic Glide Vehicles (HGV)**: Launched from a rocket, similar to regular ballistic missiles, before gliding to a target.
  - **Hypersonic Cruise Missiles (HCM)**: Powered throughout their flight via Scramjet engines.

6.4. GSAT-7R

Why in the News?

GSAT-7R (CMS-03) Satellite was successfully launched aboard the **ISRO**'s LVM3 from the Satish Dhawan Space Centre, Sriharikota.

About GSAT-7R (CMS-03) Satellite Communication

- Part of India's advanced defence satellite communication **series GSAT-7.**
- **Orbit:** Launched into the Geosynchronous Transfer Orbit (GTO), it will eventually settle into Geostationary Orbit.
- **Coverage:** Provides multi-band telecommunication services across the Indian Ocean Region and Indian landmass up to **2,000 kms from India's coastline**.
- **Multiple Communication channels**: The satellite operates on multiple frequency bands. The system enables the transmission of voice, video and data.
- **Lifespan**: 15 years and will replace the multi-band communication satellite GSAT-7/**INSAT-4F Rukmini**.
- **Purpose:** Strengthens space-based communication, maritime domain awareness, and secure links among Navy ships, submarines, aircraft, and Maritime Operations Centres.

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Other Satellites in the GSAT-7 Series

- **For Navy: GSAT-7 (Rukmini):** It is India's **first officially dedicated military satellite**.
- **For Air Force**:
  - **GSAT-7A (Angry Bird):** It helps the IAF connect various platforms **like aircraft, helicopters, UAVs, Airborne early warning and control (AWACS) aircraft**, missile units and radars.
  - **GSAT-7C:** To be developed and includes ground hubs for real-time, secure communication.
- **For Army**: **GSAT-7B**: To be developed to enhance surveillance and communication in border areas.

6.5. MK-II (A) LASER- DIRECTED ENERGY WEAPON (DEW) SYSTEM

Why in the News?

DRDO successfully conducted a **trial of an Mk-II (A) LASER- Directed Energy Weapon (DEW) system** at the National Open-Air Range (NOAR) in Andhra Pradesh.

More on the News

- India joined group of countries such as **US, China, and Russia** who possess advanced **LASER weapon capabilities**.
- Also, recently, **Israel becomes First Country** to shoot down enemy Drones with Laser Weapon.
  - Israel Air Force's Aerial Defense Array used the **prototype laser air defences.**
  - It is described as an **adapted version** of the **Iron Beam system**, a **High Energy Laser Weapon System (HELWS)**.

About Mk-II (A) DEW system

- **Developed** indigenously by DRDO's Centre for High Energy Systems and Sciences (CHESS), Hyderabad.
- **Mechanism:** Once detected by a radar or inbuilt Electro Optic (EO) system, it engages targets and uses an intense **high-energy 30 kilowatt LASER Beam**.
- **Characteristics:** Lightning speed of engagement, precision, and can have lethality delivered to the target within a few seconds.

About Directed Energy Weapons

- They **use concentrated energy from electromagnetic** or **particle technology**, rather than kinetic energy, to degrade or destroy targets.
- **Types:** High Energy LASER (HELs), High power microwave weapons (HPMs), millimeter waves, Particle beams weapons.
- DEWs generally have a shorter range than conventional weapons, and weather conditions—such as fog and storms—can make certain DEW less effective.

Other DEW Systems

- **USA:** High Energy Laser with Integrated Optical-dazzler and Surveillance **(HELIOS)** system
- **China: Hurricane-3000** and **Silent Hunter**
- **UK: DragonFire**, Radio Frequency Directed Energy Weapon **(RFDEW)**
- **Russia:** Peresvet laser
- **India:** Integrated Drone Detection and Interdiction System (**IDD&IS) Mk2A** by DRDO

6.6. STRATOSPHERIC AIRSHIP PLATFORM (SAP)

Why in the News?

DRDO conducted maiden flight-trials of Stratospheric Airship Platform (SAP).

More on the News

- It has been developed by **Aerial Delivery Research and Development Establishment**, Agra.

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- It will enhance India's **earth observation** and **Intelligence, Surveillance & Reconnaissance (ISR)** capability.

About the Stratospheric Airship Platform (SAP)

- A high-altitude, unmanned airship designed to operate in the stratosphere, typically between **17 to 22 kilometers** above Earth.
- Functions as a **High-Altitude Pseudo-Satellite (HAPS)** that can remain airborne for extended durations.
  - **HAPS** can be classified as **aerodynamic** (or heavier-than-air, e.g. fixed wing/airplanes) and **aerostatic** (or lighter-than-air, e.g. balloons and airships).
- **Lift Mechanism**: Uses **helium** for buoyancy
- **Power Source**: Generally powered by **solar energy** with onboard batteries for night-time operation.
- **Strategic Advantages**: They can carry **imaging sensors**, **radar**, and telecom payloads, making them useful for border monitoring, disaster response, and intelligence missions.
  - They bridge the gap between **drones** and **satellites**, providing space-like coverage with faster deployment, lower costs, and more flexibility.

6.7. AIRCRAFT/HELICOPTER

6.7.1. ADVANCED MEDIUM COMBAT AIRCRAFT (AMCA)

Why in the News?

Defence Minister approved **Fifth-Generation Fighter Jet Execution Model** through Industry Tie-Up.

More on the News

- India will jointly manufacture advanced jet engines for **5th generation fighter jet aircraft** named **Advanced Medium Combat Aircraft (AMCA)** programme with French aerospace major Safran.
  - Currently **only the US (F-22 and F-35), Russia (Sukhoi Su-57),** and **China (Chengdu J-20) have developed** operational fifth generation aircraft.

AMCA Programme Overview

- **Lead Agency:** Aeronautical Development Agency (ADA) under DRDO.
- **Core Capabilities:** Supercruise, internal weapons bays, AI-driven avionics, radar-absorbing structures, etc.
- **Variants:** AMCA Mk1 with GE-F414 engines; Mk2 planned with indigenous engines.

Key Features of 5th Generation Fighters

- **Powered by Twin-engine:** Provides higher level of air safety and survivability in the event of failure of one engine especially at night.
- **Stealth Capabilities**: Harder to detect by enemy radar.
- **Other:** High maneuverability, fly at supersonic speeds, etc.

Other latest Generation of Jets

Generation	Specifications	Examples
Fourth generation jet fighters (1970- 1980s)	Ability to both **switch and swing roles** between air-to-air and air-to-ground.	MiG-29, F-16, Mirage-2000 etc.
Four and half generation jet fighters	Added **'stealth',** radar absorbent materials, thrust vector-controlled engines, to extend the range of fourth generation fighters.	Eurofighter Typhoon, Rafale etc.

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6th-Gen Aircraft Programme

- **Sixth-generation fighter jets** are characterized by attributes such as **AI integration, Hypersonic capabilities, Unmanned capabilities, etc.**
- China flew two sixth-generation fighter prototypes, the J-36 and J-50.

6.7.2. OTHER AIRCRAFT/HELICOPTER IN NEWS

Helicopter/Fighter jet	Key Detail/Features
Apache AH-64E	➤ **Multi-role attack helicopter.** ➤ A **fully integrated weapon system** equipped with **Hellfire missiles, rockets,** and **chain gun.** ➤ Has **advanced sensors, radar,** and **night vision capabilities.**
LCA Mark-1A	➤ **Advanced** version of **the LCA Tejas.** ➢ **LCA Tejas** is a **4.5 generation,** all weather and multi-role fighter aircraft. ➤ Equipped with **AESA Radar, EW suite** consisting of **radar warning and self-protection jamming, Digital Map Generator (DMG),** etc.
Rafale Marine (M)	➤ **Manufacturer:** Dassault Aviation, a French aerospace company. ➤ **Omnirole capabilities:** This means able to carry out all combat aviation missions such as air defense, strikes, reconnaissance, nuclear deterrence, etc. ➤ **Generation:** 4.5 generation with maximum speed **1.8 Mach.** ➤ **Other key features:** Low-observability to radar, ability to super-cruise and extreme maneuverability at all speeds. ➤ These fighter jets will be for the Indian **Navy** and will be deployed on the **country's first indigenous aircraft carrier INS Vikrant.**

6.8. SHIPS

Ship	Key Detail/Features
INS Arnala	➤ Named after the **historic coastal fort off Maharashtra.** ➤ **India's first Anti-Submarine Warfare Shallow Water Craft** (ASW-SWC). ➤ **Largest** Indian Naval warship to be propelled by a **Diesel Engine-Waterjet combination.**
INS Nistar	➤ **First indigenously** designed and constructed Diving Support Vessel. ➤ Installed with state-of-the-art **Diving Equipment** with capability to undertake **Deep Sea Saturation Diving** up to 300 m depth. ➤ Will serve as **'Mother Ship'** for the **Deep Submergence Rescue Vessel (DSRV),** to rescue and evacuate personnel.

6.9. OTHER IMPORTANT NEWS

6.9.1. RUDRASTRA

Successful Trial of the Hybrid Unmanned Aerial Vehicle (UAV) Rudrastra Conducted at Pokhran, Rajasthan.

About Rudrastra

- A **Hybrid Vertical Take-Off and Landing (VTOL) UAV** manufactured by **Solar Defence and Aerospace Limited (SDAL).**

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- **VTOL UAVs** can take off and land **vertically, eliminating the need for runways, and** providing **manoeuvrability** and **versatility** in operations.
- **Features:**
  - Equipped with **precision-guided anti-personnel warheads**.
  - Can relay back **live video** and **return** to the launch position in **automated mode.**

6.9.2. BHARGAVASTRA

India has successfully test-fired an indigenously developed **anti-drone system**, Bhargavastra.

About Bhargavastra

- A low-cost, **'hard kill' anti-drone system** designed to neutralize threats from drone swarms.
- **Two-layer security system**:
  - **Layer 1**: Unguided micro-rockets with a 20m lethal radius for swarm drones
  - **Layer 2**: Guided micro-missiles for precision strikes

6.9.3. LONG-RANGE GLIDE BOMB 'GAURAV'

DRDO successfully conducts release trials of indigenously developed Long-Range **Glide Bomb 'Gaurav'**.

- **Glide bomb** after launch steer towards the target using highly accurate hybrid navigation scheme with a combination of Indian Navigation System (INS) and Global Positioning System (GPS) data.

About Gaurav

- **Weight**: 1,000 kg class
- **Range:** 'Gaurav' achieved 100 km range with pinpoint accuracy.

6.9.4. FIBER OPTIC DRONES

Recently used in the **Russia-Ukraine conflict**, fiber optic drones are seen as a game-changer in drone warfare due to their **resistance to electronic warfare (EW)**.

About Fiber Optic Drones

- Operated using **long fiber optic cables** instead of radio links.
  - Fiber optic cable is made up of a **collection of glass tubes** spun as thin as hairs.
  - They can support **faster speeds, longer distances, and simultaneous communications.**
  - A single fiber can carry multiple signals simultaneously on different wavelengths
- No radio link means they cannot be jammed or intercepted by EW systems.

6.9.5. PROJECT 17A

Two multi-mission stealth frigates of **Project 17A** – **INS Udaygiri** and **INS Himgiri**, were commissioned into the Indian Navy.

About Project 17 A

- Follow-on ships of **Shivalik-class (Project 17) frigates.**
  - Under it, **Seven Frigates being indigenously built** by Mazagon Dock (Mumbai) and GRSE (Kolkata).
- Configured with **Combined Diesel or Gas (CODOG) main propulsion plants**, comprising a Diesel Engine and Gas turbine.

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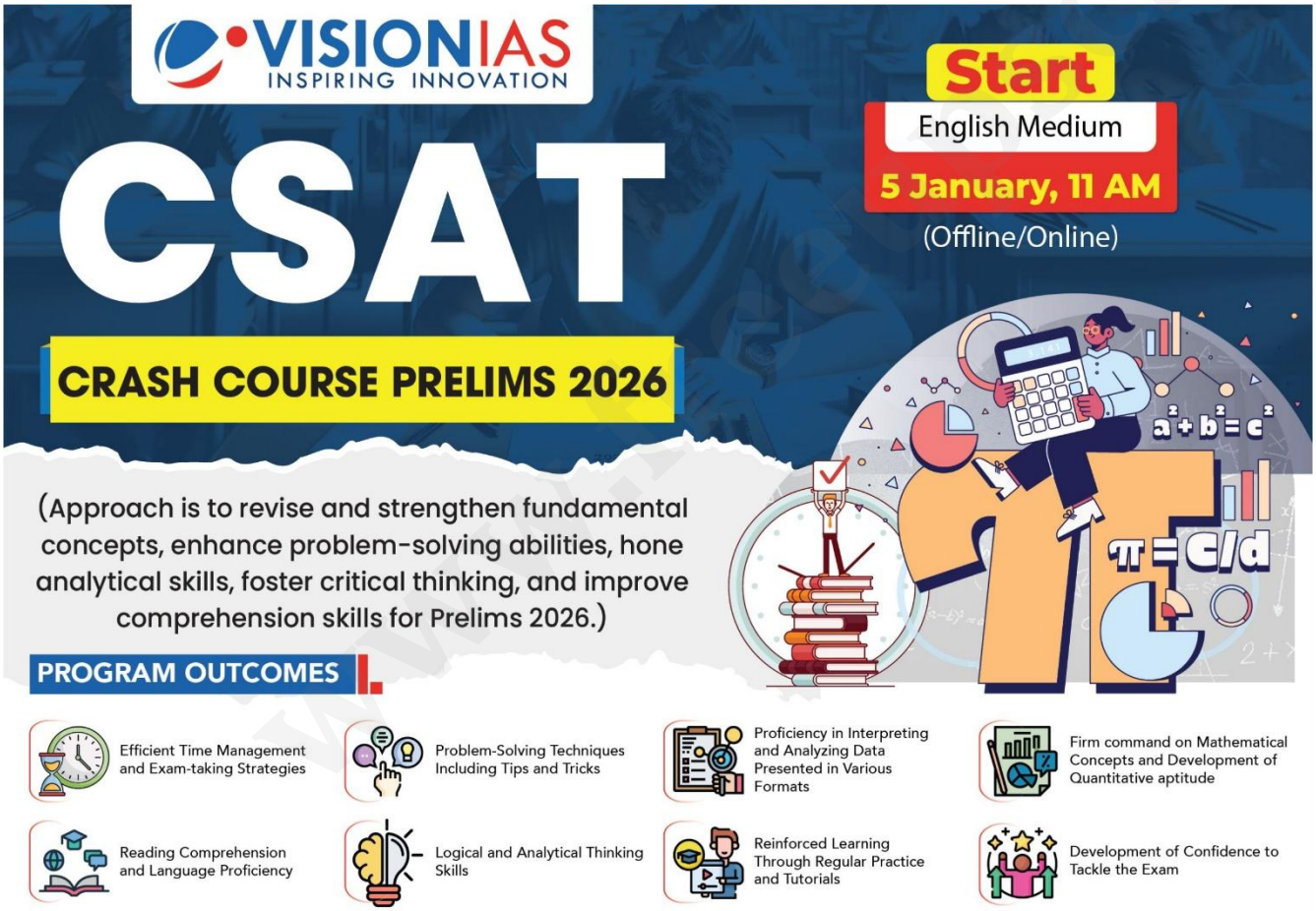
6.9.6. NETRA MKII

The government has given a go-ahead to the production of next generation **airborne early warning** and **control system (AWACS) India programme** also referred to as **the Netra MkII.**

Netra MkII

- It will be mounted on the **Airbus A321 platform.**
- **Key Features:**
  - Detect, track, and monitor threats across vast distances.
  - Much more than an aircraft as it is a flying command centre which will extend our national vigilance.



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7. ALTERNATIVE ENERGY

7.1. NUCLEAR ENERGY

Nuclear Fission and Fusion

Comparison between Nuclear Fission and Fusion

Parameter	Fission	Fusion
Process	Fission occurs when **a neutron slams into a larger** atom, forcing it to excite and split into two smaller atoms. Additional neutrons are also released that can initiate a chain reaction.	Fusion occurs when **two atoms slam together** to form a heavier atom, like when two hydrogen atoms fuse to form one helium atom.
Fuel	Uranium, plutonium etc.	Generally two hydrogen (H) isotopes- deuterium (D) and tritium (T).
Energy Production	Less energy per kilogram of fuel than fusion	Fusion could generate four times more energy per kilogram of fuel than fission
Energy requirement	Requires less energy to split two atoms in a fission reaction	To achieve fusion, the plasma in the tokamak must reach 150,000,000 °C
Technology and Application	The technology of nuclear fission is mature and has a proven track record.	Still at the experimental stage
Waste	Waste has unstable nuclei; some of these are radioactive for millions of years. Such as iodine, caesium, strontium, xenon etc.	Fusion on the other hand does not create any long-lived radioactive nuclear waste. Only helium and neutrons.
Occurrence	Does not occur naturally on Earth; needs reactors.	Happens naturally in stars (e.g., the sun).

NOTE: Net Energy Gain (NEG) is critical for **commercial** fusion power, which implies nuclear fusion process generates more energy than the nuclear fusion process consumes

7.1.1. TOKAMAK REACTORS

Why in the News?

World's biggest nuclear fusion project, ITER has completed its **central magnet system**, with **India playing a critical role in building several key components**.

More on the News

- India has **manufactured cryostat,** an enormous chamber that houses the entire ITER Tokamak.
- India has also **built cryolines** that carry **liquid helium** to cool **magnets**.

About ITER

- **Objective**: To demonstrate the viability of fusion as an abundant, safe, carbon-free energy source.
- **Located** in France.
- **India's Membership**: **Institute for Plasma Research in Ahmedabad** is lead institution from India participating in the project.

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About Tokamak Reactor

- **Purpose:** Designed to harness the energy of fusion.
- **Working:** In it, **fusion plasma** is created and confined by strong magnetic fields.
  - **Plasma** is a **fundamental state of matter** along with **solids, liquids and gases.**
- **Other Major Tokamak Reactor: Joint European Torus (JET)** in UK, **Experimental Advanced Superconducting Tokamak (EAST)** in China, **Korea Superconducting Tokamak Advanced Research (KSTAR)** in South Korea, JT-60SA (built and operated by Japan and Europe in Japan).

India's activities in nuclear fusion and Tokamak Research

- **ADITYA: First indigenously** designed and built **tokamak** by Institute of plasma research**.**
- **ADITYA-U Tokamak:** A **medium-size air-core tokamak**.
- **Steadystate Superconducting Tokamak-1 (SST-1):** Medium size superconducting tokamak

7.1.2. FAST BREEDER REACTOR

Why in the News?

India's **first Fast-Breeder Nuclear Reactor** (500 MWe) is set for commissioning by 2026.

About Fast Breeder Reactor

- **Genesis**: Government established **Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI)** to construct and operate **Prototype Fast Breeder Reactor (PFBR)**.
- **Functioning:**
  - Uses indigenously produced **Uranium-Plutonium Mixed Oxide (MOX) fuel** and utilize **liquid sodium** as a **coolant**.
  - **Uranium-238 blanket** surrounding fuel core will undergo nuclear transmutation **to produce more fuel,** thus earning the **name 'Breeder'.**
- **Location:** Kalpakkam, Tamil Nadu

Significance of FBR

- **Technological Advancement:** Once commissioned, **India** will only be the second country after **Russia** to have commercial operating FBR.
- **Utilization of Thorium Reserve:** The **operationalization of PFBR** will mark the start of **stage II** of India's **three-stage nuclear power program**.
  - By **transmutation**, Thorium will create fissile U-233 which will be used as fuel in the **third stage**.
- **Safety**: passive safety features ensuring a prompt and safe shut down of the plant in the event of an emergency.

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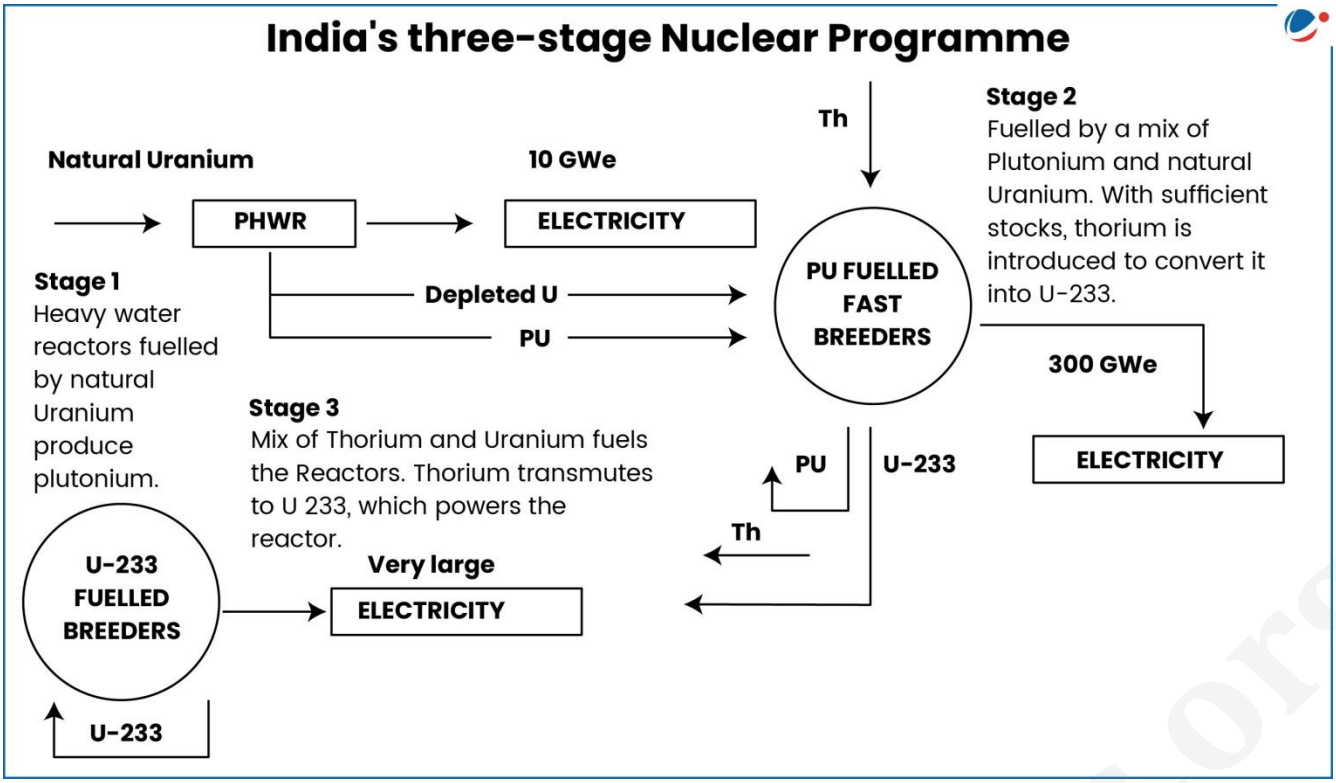

Related News

Mahi Banswara Rajasthan Atomic Power Project (MBRAPP)

- PM laid the foundation of the **Mahi Banswara Rajasthan Atomic Power Project (MBRAPP).**
- **About MBRAPP Project**
  - **Capacity**: 4 x 700 MWe **PHWR (Pressurized Heavy Water Reactor)**
  - It will be developed by **Anushakti Vidhyut Nigam (ASHVINI)**.
    - **ASHVINI** is a joint venture between **Nuclear Power Corporation India Limited (NPCIL)** and **National Thermal Power Corporation Limited (NTPC)**.
  - **The project** is part of India's "**fleet mode**" initiative.
    - Under this **Initiative**, ten identical 700 MW reactors are being built across India under uniform design and procurement plans.

Enrichment of uranium

- Recently, concerns have been raised on Iran's resumption of **enrichment of uranium.**
- **About Enrichment of uranium**
  - To enrich uranium means taking the naturally found **element and increasing the proportion of uranium-235 while removing uranium-238.**
  - **Method:** Mainly done **using centrifuges.**
  - **Enrichment Levels & Uses**
    - **(3–5%) U-235:** Civilian nuclear power reactors.
    - **(>20%) U-235:** Highly enriched uranium (HEU), potential for weapons.
    - **(~90%) U-235:** Weapons-grade, compact and efficient for **nuclear arms**.

7.1.3. THORIUM MOLTEN SALT REACTOR (TMSR)

Why in the News?

China successfully achieved the first-ever thorium to uranium fuel conversion in a Thorium Molten Salt Reactor (TMSR)

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About Thorium Molten Salt Reactor (TMSR)

- It is **fourth-generation** advanced nuclear energy system that uses **high-temperature molten salt** as a **coolant**.
  - China's TMSR is currently the only operational molten-salt reactor in the world.
- **Key Features**: Cool without water, **run** at **atmospheric pressure**, deliver a **high-temperature output**, etc.
- **Key Advantages**:
  - **Passive Safety Features**: If an MSR is too hot, a salt plug melts, stopping the reaction.
  - **Small High-Level Nuclear Waste Footprint**: Thorium generates fewer long-lived minor actinides (radioactive metallic elements) than plutonium fuels.
  - **Other**: Extract more energy from fuel, etc.

Thorium Fuel

- Thorium has to be converted to **Uranium-233** in a reactor before it can be used as fuel.
  - Thorium-232 is the only naturally occurring isotope of thorium.
- It is **three times more abundant** in nature than uranium.
  - Despite its widespread availability, the metal's utilisation is restricted by its high extraction cost.
- **Advanced Heavy Water Reactor**, currently under development with **Bhabha Atomic Research Centre (BARC)**, would serve as a technology demonstrator for thorium fuel cycle.
  - Also, India is developing an **Indian Molten Salt Breeder Reactor (IMSBR)**.

Thorium reserves in India

- India has the world's largest reserves of thorium.
- Kerala and Odisha have rich reserves of **monazite**, which contains about 8 – 10% thorium.
- It is also found in Andhra Pradesh, Tamil Nadu, West Bengal and Jharkhand.

7.2. LITHIUM-ION (LI-ION)

Why in the News?

India's Largest Lithium-ion (Li-ion) Battery (**LIB)** manufacturing plant was inaugurated in Haryana.

About Li-ion Battery

- It is a type of **rechargeable battery.**
- In it, lithium ions move between a **negative electrode** (graphite) and a **positive electrode** (Li transitional metal oxides) through a **non-aqueous electrolyte** during charging and discharging.

Benefits of Lithium-ion Batteries

- **High energy density**: Stores more energy compactly and offers **longer cycles** between charges.
- **Lightweight and Lower Toxic Heavy Metals**: Compared to older **lead-acid batteries**, it is much lighter due to use of less toxic and lightweight **Li and carbon electrodes**.
- **Excellent performance**: They provide **good cycle stability, efficiency, and reliability**, with low self-discharge and generally **no memory effect (**slow-down due to repeated charging**)**.

Related News

Black Mass Recovery Technology

- Technology Development Board (TDB) has extended financial support for the commercialization of an **indigenous battery recycling technology** that utilizes **dual-mode (wet and dry) black mass recovery.**
- **What is Black Mass?**
  - When a lithium-ion battery reaches the end of its life, it doesn't stop being valuable. Inside that used battery is a **dark, powdery substance known as black mass** — a mix of critical minerals.
  - This can be recovered, refined, and reused to power the next generation of clean energy.
  - **Black mass recovery technology:** It is a **process** that extracts valuable materials like lithium, cobalt, and nickel from used lithium-ion batteries.

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Sodium-Ion Battery (SIB)

- Research team working under Department of Science and Technology has developed a **super-fast charging sodium-ion battery (SIB)** that can charge up to **80% in just six minutes** and last over **3000 charge cycles.**
- **About Sodium-Ion Battery (SIB)**
  - SIBs are a **type of rechargeable battery** similar to lithium batteries, but carry the charge using sodium ions (Na+) instead of lithium ions (Li+).
  - **Advantages of Sodium-Ion Batteries (SIBs) Compared to LIBs:**
    - **Energy density:** SIBs generally have **lower energy density** than Li-ion
    - **Safety:** SIBs can be transported at zero voltage (fully discharged), reducing fire risks.

7.3. VANADIUM REDOX FLOW BATTERY

Why in the News?

India's largest and first MWh-Scale Vanadium Redox Flow Battery (VRFB) inaugurated at NTPC NETRA.

More on the News

- **Flow Batteries**, along with **solid state batteries**, are one of the next generation battery technologies and are emerging as an **alternative to lithium-ion** for grid-scale applications**.**

About Next Generation Battery Technologies

- **Flow Batteries:** Flow batteries are powered by **reduction-oxidation (redox) reactions** and involve **two different liquid electrolytes** that pass ions or protons back and forth through a porous membrane.
  - These batteries can **store larger amounts of energy**—as much as the size of the electrolyte cells can contain—and don't use flammable or polluting materials.
  - **Types of Flow Batteries:** Vanadium Redox, Zinc–Bromine, Iron–Salt/Organic systems.
- **Solid-State Batteries:** These use **solid electrolyte solutions**, which don't need a different separator.
  - SSBs have several advantages over conventional batteries
    - Improved safety where solid electrolytes are less prone to leakage or combustion compared to liquid electrolytes,
    - Potential to store more energy in the same volume or weight
    - Capable of recharging up to 4–6 times faster than liquid electrolyte batteries, etc.

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8. MISCELLANEOUS

8.1. GEOSPATIAL TECHNOLOGY

Geospatial Technology

NCEPT Corner

Geospatial Technology

- **Geospatial technology** refers to a set of tools and techniques used to collect, analyze, and visualize spatial and geographic data.

Components of Geospatial Technology

Geographic Information System (GIS)	Global Positioning System (GPS)	Remote Sensing (RS)	Cartography and Spatial Analysis
Captures, stores, and analyzes spatial data. Helps in mapping and visualization of geographic features. Used in urban planning, agriculture, and disaster response	Uses satellite signals to determine precise locations. Essential for navigation, transportation, and military operations.	Collects data from satellites and aerial platforms. Monitors environmental changes, land use, and natural disasters. E.g. **LiDAR**	Represents geographic data in maps. Aids in policy-making and resource management.

8.1.1. OPERATION DRONAGIRI

Why in the News?

Haryana has constituted state and district-level committees for the implementation of Operation Dronagiri.

About Operation Dronagiri

- A pilot project under **National Geospatial Policy 2022**, and will be implemented by Geospatial Innovation Cell, Department of Science and Technology.
- **Purpose**: To demonstrate the potential applications of geospatial technologies and innovations in improving the quality of life of citizens and ease of doing business.
- **First Phase Implementation**: In the states of UP, Haryana, Assam, Andhra Pradesh & Maharashtra.
- Focus is on Agriculture, Livelihoods, Logistics and Transport , Urban Planning and Infrastructure.
- development of an **Integrated Geospatial Data Sharing Interface (GDI)**

National Geospatial Policy 2022

- **Vision**: Position India as global leader in geospatial sector, develop national framework, and enable availability of geospatial data.
- **Institutional Framework**: Policy provided for establishment of **Geospatial Data Promotion and Development Committee** as apex body for formulating guidelines and programs for promotion of Geospatial sector.
- **Nodal Agency**: Survey of India (SoI)

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Other key Initiatives taken to Promote Geospatial sector

- **National Geospatial Mission**: Aims to develop foundational geospatial infrastructure
- **National Geospatial Data Repository**: Serves as a centralized platform for geospatial data management and access.
- **Continuously Operating Reference Stations (CORS) Network:** Launched by SoI

8.2. CRITICAL MINERALS

Why in the News?

The Quad (United States, Japan, India, and Australia) launched the **Critical Minerals Initiative**.

What are Critical Minerals?

- Critical minerals are **naturally occurring elements or compounds**.
  - These are classified as critical due to **high demand** (diverse applications), **supply risks**, etc.
- **Ministry of Mines** has released a list of 30 critical minerals.
  - These minerals are - Antimony, Beryllium, Bismuth, Cobalt, Copper, Gallium, Germanium, Graphite, Hafnium, Indium, Lithium, Molybdenum, Niobium, Nickel, PGE, Phosphorous, Potash, Rare Earth Elements (REEs), Rhenium, Silicon, Strontium, Tantalum, Tellurium, Tin, Titanium, Tungsten, Vanadium, Zirconium, Selenium, and Cadmium.

Other initiatives taken to secure Critical Minerals supply

- **India**
  - **Mines and Minerals (Development and Regulation) Amendment Act, 2023,** enables exploration and mining of critical minerals.
  - **National Critical Mineral Mission (NCMM)**
  - **National Mineral Policy, 2019**
- **International Collaborations & Agreements**
  - **Minerals Security Partnership (MSP)**: India joined this US-led initiative in 2023.
  - **Khanij Bidesh India Limited (KABIL):** A joint venture company of Ministry of Mines to acquire critical minerals globally.

Related News

Nickel-Copper-Platinum Group Element (Ni-Cu-PGE) Sulphide

- India's first ever discovery of **Nickel-Copper-Platinum Group Element (Ni-Cu-PGE) sulphide** at Bhalukona-Jamnidih block of the Mahasamund district in Chhattisgarh.
- **Applications of Ni-Cu-PGE**
  - **Nickel:** Used in stainless steel, alloys, and batteries (especially for EVs).
  - **Copper:** Electrical wiring, electronics, plumbing, construction.
  - **PGEs:** Catalysts, jewellery, electronics, and hydrogen fuel cell technology.
- **Strategic Value:** Critical for clean energy technologies, EVs, and defence applications, making it a key mineral group for energy transition.

8.2.1. RARE EARTH ELEMENTS (REES)

Why in the News?

In retaliation to US tariffs, China restricts exports of Rare Earth Elements (REEs).

What are REEs?

- REEs are a **set of 17 lustrous, silvery-white, soft heavy metals** in periodic table, **e.g.,** Cerium (Ce), Yttrium (Y), Europium (Eu), etc.
  - Though **found abundantly,** however, they are difficult to extract as they are **not found in concentrated form.**

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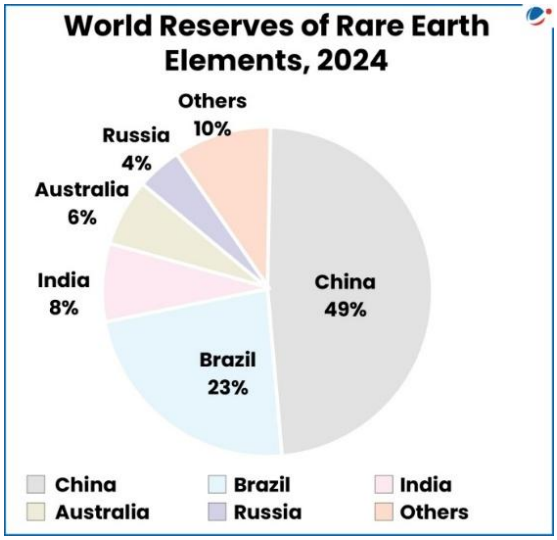
- **Potential Applications:**
  - **Electronics and Electricals:** E.g., used in television screens and computer monitors because many REE have phosphorescent properties.
  - **Renewable Energy and Green Technologies:** REE alloys prevent corrosion in metals and increase efficiency in energy storage.
  - **Rare Earth Magnets:** REE magnets have high remanence and coercivity.
  - **Other:** Defence (e.g., radars), industrial catalyst, etc.
- **China dominates** with **more than 2/3rd of global production** and **controls more than 85% of the global supply chain.**



Distribution of REE in India

- India's REE reserves are mostly found in **monazite sands**.
- **Coastal states** have the most **rare earth deposits**, namely T**amil Nadu**, **Kerala**, **Andhra Pradesh**, and **Odisha**. (2023 Indian Minerals Yearbook).

8.3. NANOTECHNOLOGY

Nanotechnology

NCEPT Corner

Nanotechnology

- Involves working with materials and devices at the nanoscale, typically ranging from **1 to 100 nm in size** (nanoparticle).
- On the **nanometer scale,** materials may exhibit unusual properties. Their properties depend on shape, size, surface characteristics, and inner structure.
- **Types:**
  - **Natural nanomaterials:** E.g. Volcanic ash
  - **Artificial nanomaterials:** E.g. Carbon Nanotube
- **Concern/Challenge:** Potential toxicity of nanoparticles to humans and the environment.

Key Applications of Nanotechnology

- **Agriculture: Nanofertilizers** (nutrient uptake with **90-100% utilization efficiency),** **Nanobiosensors** (Monitor soil conditions), etc.
- **Health:** Better imaging and diagnostics, Targeted Drug Delivery, etc.
- **Energy: Nanostructured solar cells** could be **cheaper** to **manufacture and easier** to **install,** etc.
- **Environment:** Nanomaterials can be employed in **water purification and desalination technologies** etc.
- **Electronics and IT:** Quantum dots and other nanostructures can be used to develop **advanced displays, lighting,** etc.
- **Other: Cosmetics** (uses nanoparticles of some metallic oxides), etc.

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8.3.1. NANOZYME

Researchers at Indian Institute of Science (IISc) developed an artificial **metal-based nanozyme** (vanadium pentoxide (V_2O_5)) to clamp down on **abnormal blood clotting** caused by conditions like **pulmonary thromboembolism (PTE).**

- Under normal conditions, an **injured blood vessel** witnesses the **activation of platelets** to form clots while under PTE **overactivation of platelets occur** causing **excess blood clots or thrombosis** leading to mortality.

About Nanozymes

- They are **nanomaterials** with **intrinsic enzyme-like properties.**
- Compared to **natural enzymes**, they exhibit the **unique advantages** including high catalytic activity, low cost, high stability, easy mass production, etc.

8.3.2. NANO FERTILIZERS

Indian Farmers Fertilizer Cooperative Limited (IFFCO) to set up its first overseas nano fertiliser plant in Brazil.

- IFFCO had launched world's first **'Nano Liquid Urea'** fertiliser in 2021 & then Nano-DAP in 2023.

About Nano Fertilizers

- Nutrients **encapsulated or coated within nanomaterial** (measuring 100 nanometres or less).
- Enables **controlled release** and its subsequent **slow diffusion into the soil**.

8.3.3. NANO SULPHUR

TERI scientists have developed nano sulphur which reportedly increased mustard yield by 30-40%.

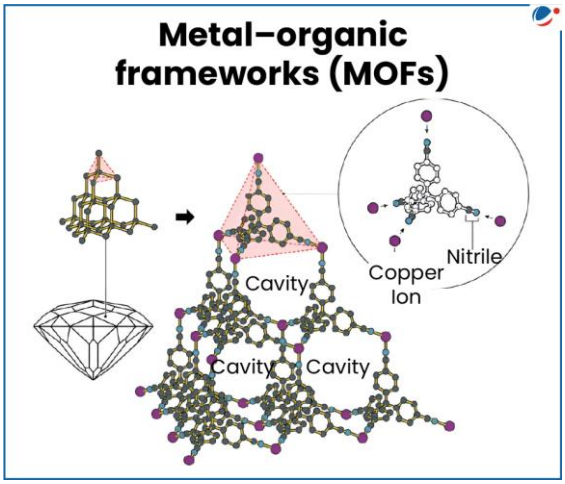
About TERI's Nano-sulphur

- It is a **completely green product** that uses biological agents like plant promoting bacteria that secrete enzymes and metabolites.
  - This makes it different from other **nono-fertilizers** such as nano urea.
- Nano-sulphur has **antibacterial and insecticidal** properties.

8.4. METAL–ORGANIC FRAMEWORK (MOF)

Why in the News?

Susumu Kitagawa, Richard Robson and **Omar M. Yaghi** are awarded the Nobel Prize in Chemistry 2025 for the development of **metal–organic frameworks (MOF).**



What is Metal–Organic Framework (MOF)?

- MOF is special material made up of **two parts**:
  - **Metal ions (e.g., copper, etc.)** – this act like the "joints" or "connecting points"
  - **Organic molecules (carbon based molecules like coal, etc.)** – these act like the "links" or "bridges" that connect the metal parts together.
- They join through chemical bonds to form a **network structure.**
  - **Structure** can be in one, two, or three dimensions with a lot of **empty spaces or cavities** between them.
- The cavities make the material **highly porous**- full of tiny holes inside **(see infographic)**.

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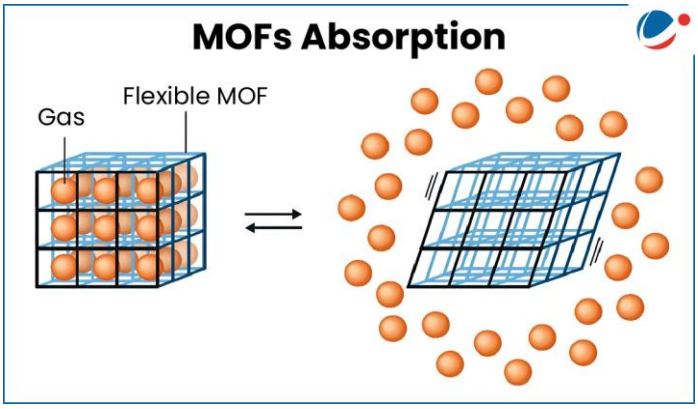
- **Origin of the Idea of MOF**: The idea to create MOFs came from studying the **structure of diamond**.

Key Features



- **MOFs** can be **customized** to absorb or trap specific kinds of materials like gases, water, or chemicals.
- **MOFs** are **more absorbent** than many other porous materials (like **zeolites**).
- They act like **molecular storehouses**, storing gases, liquids, or other materials.

Key Applications

- **Water collection from dry air**: MOFs can capture water vapour from desert air.
- **Food Processing**: MOF based packaging materials can store the ethylene gas (a plant hormone) into its cavity, reducing the concentration of ethylene and increases the shelf life.
- **Pollution control:** Extracting pollutants, such as separating PFAS, antibiotics etc. from polluted water.
- **Rare-Earth Elements:** Experimentally mining rare-earth elements from wastewater.
- **Gas storage**: Storing gases such as hydrogen, carbon dioxide, methane etc.

8.5. ELECTRIC VEHICLES (EVS)

Why in the news?

NITI Aayog launched first **India Electric Mobility Index.**

About India Electric Mobility Index (IEMI)

- **First-of-its-kind** tool to benchmark states' progress in e-mobility, was launched in partnership with **World Resources Institute India.**
- Tracks 16 performance indicators under 3 thematic categories-**Transport Electrification Progress; Charging Infrastructure Readiness; EV Research & Innovation.**
- Groups states into 4 categories: **Achievers, Front Runners, Performers, and Aspirants.**
  - For 2024, **Delhi topped** with a score of 77, followed by **Maharashtra** (68).

About Electric Vehicles (EVs)

- **Types: Battery EVs** (entirely battery-powered); **Hybrid EVs** (have both engine and electric motor); **Fuel Cell EVs** (utilize 'fuel cell technology' to generate electricity for propulsion); **Plug-in Hybrid EV** (uses both an engine and a rechargeable battery) etc.
  - **Main Components of BEV:** Electric motor, Inverter, Battery, Control Module, Drive train etc.
  - **Working Principle:** Power for electric motor is converted from **DC Battery to AC.**

Note: Alternative powertrains include propulsion systems that are not based exclusively on the popular internal combustion engine. E.g., full battery electrics, hydrogen fuel cells, etc.

Other recent steps taken by India to boost EV adoption

- **PM E-DRIVE Scheme**: Central Sector scheme supporting e-2Ws, e-3Ws, e-trucks, e-buses, e-ambulances, and charging infrastructure.
- **PM e-Bus Sewa – PSM (Payment Security Mechanism) Scheme:** Deployment of 38,000+ e-buses.
- **PLI – Advanced Chemistry Cell:** Supports 50 GWh domestic battery manufacturing
- **EVolutionS program**: Launched by Department of Science & Technology (DST) for EV startups.
- **Other**: Promoting **Acoustic Vehicle Alerting System (AVAS),** PLI Scheme for Automobile & Auto Components, etc.

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Related News

Vehicle-to-Grid (V2G) Technology

- Kerala State Electricity Board (KSEB) and IIT Bombay have initiated a pilot project to explore the implementation of Vehicle-to-Grid (V2G) technology.
- **About V2G Technology**
  - V2G refers to **technologies that enable EV batteries to send power back to the grid.**
    - When an EV is not in use, it can act as a **decentralised battery energy storage device**.
  - By incorporating V2G technologies, EVs offer an opportunity to facilitate the **integration of Renewable Energy (RE) and support a demand response** market.
  - It can also help **modulate power in an EV battery to reduce the impact of variable RE** on the grid and improve grid stability.

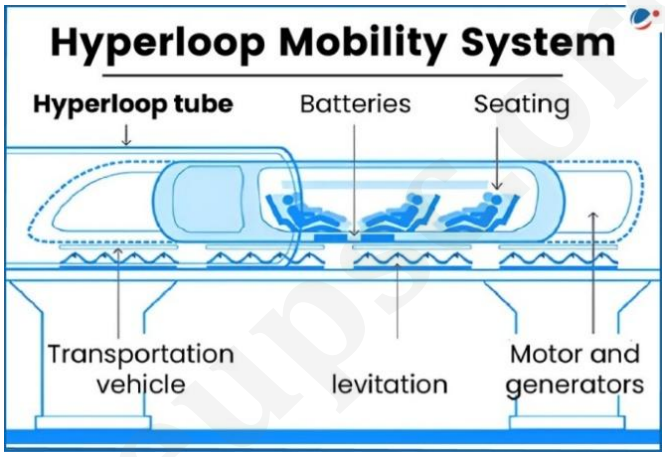
8.6. HYPERLOOP MOBILITY SYSTEM

Why in the News?

Maharashtra inks deal with IIT Madras startup (TuTr Hyperloop Pvt Ltd) to build hyperloop.

More on the News

- The proposed **Linear Induction Motor (LIM)-based hyperloop mobility system** will connect **Jawaharlal Nehru Port Trust in Navi Mumbai** to the **upcoming Vadhavan Port.**



About Hyperloop Mobility System

- **Concept**: It is basically a **magnetic levitation (maglev) system** where pods travel at **ultra-high speeds through low-pressure tubes.**
- **Its Functioning and Key Components**
  - Hyperloop functions in a **sealed tube with minimal air resistance**, utilizing **vacuums** and **magnetic levitation** for hovering.
  - **Linear Induction Motors (LIM)** propels pods silently enabling the theoretical speed of 1,200 km/h.
- **Key components**: Steel tubes, pressurized capsules, a compressor for airflow, and air bearing suspension.
- **Advantages:** Ultra-high speeds (e.g., Mumbai-Pune in 25 mins), energy efficiency (potentially carbon-free), noise reduction, and logistics redefinition (moving cargo quickly and efficiently).

8.7. DEEP OCEAN MISSION (DOM)

Why in the News?

Samudrayaan Mission will be launched by 2026 end as per the **National Institute of Ocean Technology (NIOT)**.

More on the News

- Recently**,** Two **Indian aquanauts** dived to depths of 4,025 meters and 5,002 meters in the **Atlantic Ocean**, placing India among a select group of nations capable of such deep-sea exploration.
  - The dives, conducted aboard the **French submersible Nautile** in collaboration with **IFREMER**, **France's marine research institute,** were led by team from **NIOT, Chennai**.
  - The dive is a **prelude to India's Samudrayaan Mission**.
- So far, **only the U.S., Russia, China, France** and **Japan** have carried out successful deep-ocean crewed missions.

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Samudrayaan Mission

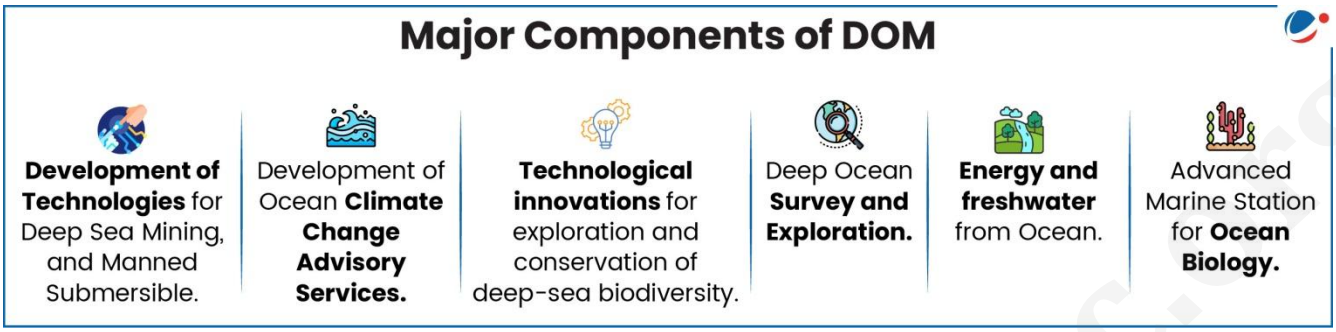
- A component of **Deep Ocean Mission (DOM).**
- **Objective:** Explore Ocean at **6,000-metre depth** using **manned submersible vehicle 'Matsya'.**

About Matsya-6000

- **4th Generation self-propelled** deep-ocean human scientific submersible vehicle.
- Being **developed** by **NIOT.**
- **Endurance** of **12 hours** under normal operation and **96 hours in case of emergency**.

About DOM

- **Nodal Ministry:** Ministry of Earth Sciences
- **Purpose:** Explore **Deep Ocean** for **resources and develop deep sea technologies** for sustainable use of ocean resources, thus supporting India's **Blue Economy** initiatives.



8.8. RESEARCH DEVELOPMENT AND INNOVATION (RDI) SCHEME

Why in the News?

Research Development and Innovation (RDI) Scheme has been launched.

Key Highlights of the Scheme

- **Aim:** Provide **long-term financing** or **refinancing** with **long tenors at low/nil interest rates** to spur private investments.
- **Nodal Department**: Department of Science and Technology
- **Fund allocation:** ₹1 lakh crore
- **Key Objectives**
  - Encourage private sector to scale up RDI in sunrise domains and sectors relevant for economic security, strategic purpose, and self-reliance
  - **Finance transformative projects at higher Technology Readiness Levels**, etc.
- **Two-Tiered Funding Mechanism**
  - **Special Purpose Fund (SPF):** Established within the **Anusandhan National Research Foundation (ANRF),** acting as the **custodian of funds.**
    - **ANRF** was established under the **ANRF 2023 Act**.
  - **Second Level Fund Managers:** Funds from SPF are allocated here, in the form of **long-term concessional loans** or **equity funding (for startups).**

8.9. OTHER IMPORTANT NEWS

8.9.1. SODAR SYSTEM

SODAR (Sound Detection and Ranging) system facility has been inaugurated at India Meteorological Department (IMD), Delhi.

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- It is designed & developed by CSIR–Advanced Materials and Processes Research Institute (AMPRI), Bhopal.

About SODAR

- **Function**: SODAR works by sending sound pulses and subsequently monitoring the intensity and frequency of the returned signal.
  - Specifically, it determines the lower-atmosphere wind profile and temperature structure.
- Provides information on height of inversion, height of fog layer, strength of turbulence etc.

8.9.2. HANSA-3 (NG)

CSIR (Council of Scientific and Industrial Research)-National Aerospace Laboratories (NAL) signs **technology transfer** deal with a private firm to manufacture HANSA trainer-planes.

About HANSA- 3 (NG)

- Powered by an advanced fuel-efficient **Rotax 912 iSc3 Sports engine.**
- **Significance:** Offers Large and world-class flying training ecosystem; strengthen India's aviation industry, etc.

8.9.3. KAVACH

Union Minister for Railways announced that **Kavach 5.0** will be implemented to upgrade Mumbai's suburban train travel.

About Kavach

- Indigenously **Automatic Train Protection** system designed to improve train safety and efficiency.
- **Function**: The Kavach assists loco pilots by displaying signals in the train and automatically applying the brakes if the pilot fails to do so.
- Ensures that the train operates smoothly even in extreme weather conditions, such as fog.
- **Radio Frequency Identification (RFID) tags** are placed throughout the entire track length to enable the Kavach to track train positions and detect any potential safety issues along the route.

8.9.4. SHINKANSEN TECHNOLOGY

Next generation E10 Shinkansen trains are to be introduced simultaneously in India (**Mumbai-Ahmedabad Bullet train project**) and Japan.

About Shinkansen Technology

- It is **Japan's High-speed bullet train.**
  - It is the **world's safest** and most **reliable high-speed, high-volume and high-frequency** transport system.
- **Key Features:**
  - **Dedicated track for high-speed rail** that is free of level crossings and **ATC system (Automatic Train Control System)**
  - **Aerodynamic optimization** of the leading shape, vehicle **noise reduction,** etc.

8.9.5. BLACK BOX

Aircraft Accident Investigation Bureau (AAIB) recovered the Black Box from the wreckage of Air India's Boeing 787.

About Black Box

- **Purpose**: Records data during flights and crucial information on plane crashes.
- **Comprise** two **Critical Flight Recording Devices**: Flight Data Recorder and Cockpit Voice Recorder.
- **Colour**: Bright orange to ensure high visibility.

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- **Material**: Made of strong substances (steel or titanium) and are insulated from extreme heat or cold.

8.9.6. ALTERMAGNETS

Scientists from **S.N. Bose National Centre for Basic Sciences (SNBNCBS)** discovered a unique **duality in alternemagnets** using **chromium antimonide (CrSb)**.

About Altermagnets

- **Definition: Altermagnets** are a **new type of magnetic material** that combine the best features of **ferromagnets** and **antiferromagnets**.
  - **Ferromagnets**: Spins align in the same direction, resulting in **strong magnetism.**
  - **Antiferromagnets**: Spins alternate, thus cancelling each other out, resulting in no external magnetism.
- **Features:**
  - Like antiferromagnets, they exhibit **alternating spins** and therefore have **no net magnetism.**
  - But due to their **unique crystal symmetry**, they show **intense internal spin polarisation**, similar to ferromagnets.
- **CrSb (Chromium Antimonide)** shows the **strongest spin-splitting** among known altermagnets.

8.9.7. ACCELEROMETER

Google's Android Earthquake Alert system has detected over 18,000 earthquakes using phone accelerometer signals.

About Accelerometer

- A sensing device that **measures acceleration** and **detects the frequency** and intensity of human movement.
- **Principle of Functioning**: Accelerometers work according to Newton's law of motion, the force on an object is equal to its mass times its acceleration.
- **Can measure both**: Static acceleration (due to gravity) & dynamic acceleration (car crash).
- **Key Applications**
  - **Digital Devices:** smartphones, Laptops, digital cameras- for rotating the display
  - **Vehicles:** Used to trigger airbags
  - **Drones:** to stabilize their orientation mid-flight

8.9.8. DESALINATION TECHNOLOGIES

IIT Bombay Scientists Developed a new **hydrophobic Graphene-based** lotus leaf-like solar evaporators **that can facilitate water desalination**.

Key Desalination Technologies

- **Thermal Technology**
  - **Heating of saline water** and **collecting the condensed vapor** (distillate) to produce pure water.
  - **Usage:** Mainly for **seawater desalination**
  - **E.g.,** Low Temperature Thermal Desalination (LTTD) plants, Lakshadweep
- **Membrane Technology**
  - Feedwater is pumped through **semi-permeable membranes** to filter out the dissolved solids.
  - **Usage:** Mainly for **brackish water desalination**
  - **E.g.,** Nemmeli Seawater Desalination Plant, Tamil Nadu, on Reverse Osmosis. (Largest desalination plant in the South Asia)

8.9.9. ADVANCED DRIVER ASSISTANCE SYSTEM

Union Government is considering mandating **Advanced Driver Assistance System (ADAS) in all new models of trucks and buses**, including school buses.

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About ADAS

- A **built-in suite of coordinated technologies** that help drivers operate their vehicles more safely and **avoid human errors**.
- In ADAS, sensors such as **Lidar, Radar, and cameras** work together to inform features such as pedestrian detection, and lane departure warning.
- Includes a range of features including Adaptive Cruise Control, Automatic Emergency Braking, Blind Spot Detection, Cross-Traffic Alert, Parking Assistance, among others.

8.9.10. BIOSTIMULANT

Minister of Agriculture and Farmers' Welfare has withdrawn approval for the sale of 11 biostimulants derived from animal sources (such as chicken feathers, pig tissue etc.).

About Biostimulant

- **Definition:** Substances and/or microorganisms whose function when applied to plants or the rhizosphere is to stimulate natural processes to benefit crop quality, independently of its nutrient content.
  - Unlike fertilisers, it does not supply nutrients directly, and unlike pesticides, it does not control pests.
- **Popular Biostimulants:** Humic acids, seaweed extracts, liquid manure composting and beneficial bacteria and fungi.
- They are regulated under **Fertiliser (Inorganic, Organic or Mixed) (Control) Order, 1985.**
- **Biostimulants** can improve Nutrient availability and use Efficiency, tolerance to stress**,** etc.

8.8.11. AGRIENICS PROGRAMME

MeitY announced the transfer of technology under the Agrienics Programme.

About Agrienics Programme

- A **national programme** of **MeitY** involving research, development, deployment, demonstration, and commercialization of technologies in agriculture and environment domain.
- **Nodal Agency**: Centre for Development of Advanced Computing (C-DAC), Kolkata.

8.8.12. METRE CONVENTION

The Department of Consumer Affairs commemorated **World Metrology Day 2025,** marking the **150th anniversary** of the **Metre Convention.**

About Metre Convention, 1875

- **Purpose:** Includes **convention and its annexed regulation** to assure the **international unification** and **improvement of the metric system.**
  - Created the **International Bureau of Weights and Measures (BIPM)** to develop and maintain a universal measurement system.
- **Significance: International collaboration** in metrology, **global uniformity** of measurements for research, trade, etc.
- **India** is a member.

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